



PCT/AU2004/000775

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WITNESS my hand this  
Twenty-fourth day of June 2004

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**PROVISIONAL SPECIFICATION**

for the invention entitled:

**"Immunomodulating compositions, uses therefor and processes for their production"**

The invention is described in the following statement:

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## IMMUNOMODULATING COMPOSITIONS, USES THEREFOR AND PROCESSES FOR THEIR PRODUCTION

### FIELD OF THE INVENTION

THIS INVENTION relates generally to modulation of immune responses. More particularly, the present invention relates to the use of at least one set of peptides in compositions and methods for modulating an immune response to one or more polypeptide antigens. In certain embodiments, the sequences of a respective set of peptides are derived in whole, or in part, from a single polypeptide antigen. Individual peptides of a respective peptide set comprise different portions of an amino acid sequence corresponding to a single polypeptide antigen and display partial sequence identity or similarity to at least one other peptide of the same set of peptides. The invention also extends to methods of using such peptides in a range of preventive, diagnostic and therapeutic applications. Additionally, the invention relates to the use of uncultured antigen-presenting cells or their precursors, which have been contacted with an antigen, in methods and compositions for modulating an immune response in a recipient of those cells.

Bibliographic details of various publications numerically referred to in this specification are collected at the end of the description.

### BACKGROUND OF THE INVENTION

Since its discovery almost 20 years ago, the human immunodeficiency virus type-1 (HIV-1) has claimed more than 22 million lives and is continuing to devastate communities worldwide (1). Forty-two million people are currently living with HIV-1 and, despite efforts to modify high-risk behaviour, an estimated 5 million new infections occur yearly (2). Similarly, Hepatitis C virus (HCV) and Hepatitis B virus infections result in chronic liver damage and hepatocellular damage in millions of people worldwide. Safe and effective preventative or therapeutic vaccines for these viruses are desperately needed. Additionally, it is now believed that immune protection from, or clearance of, many cancers requires specific T cell responses.

The elimination of persistent intracellular pathogens such as replicating viruses generally requires the mobilisation of cell-mediated immunity (CMI). CD8+ cytotoxic T lymphocytes (CTL) are the primary effector cells of CMI; they kill viral-infected cells by recognising viral peptides presented on the cell surface in the context of MHC class I

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molecules. Prior to the appearance of virus-specific antibodies, a robust HIV-1-specific CTL response temporally correlates with reduced viremia during the acute stage of HIV-1 infection (3, 4). Furthermore, strong CTL responses are associated with reduced HIV-1 viremia during chronic infection (5, 6), whereas a decline in HIV-1-specific CTL is linked 5 to rapid progression to AIDS (4, 7-9). Similarly, clearance of HCV infections is generally thought to be assisted by virus-specific T cell responses.

There are no effective vaccines against HIV-1, HCV or cancers. Early HIV-1 vaccine strategies were based on whole-inactivated virus and recombinant structural proteins such as the envelope (env) glycoprotein. Non-human primate models revealed 10 only limited strain-specific protection by these vaccines against pathogenic simian immunodeficiency virus (SIV) and highly pathogenic SHIV (SIV-HIV-1 chimeric) challenges (10-13). The first human phase III trials also failed to show efficacy (14).

Particle- and recombinant whole protein-based vaccines, although safe, favour the generation of antibodies that are insufficient for protection against many chronic viral 15 pathogens. Alternatively, intracellularly expressed antigens are subsequently more likely to induce CTL responses. Live-attenuated viruses generate potent cell-mediated immunity (CMI) responses, however their clinical safety is of concern (15). Consequently, much focus has shifted toward genetically engineered vectors (such as DNA plasmids and poxviruses) expressing HIV-1/SIV genes (such as *env*, *gag* and *pol*) or HCV genes (16).

It is not known which immune-target antigens are protective, but a large breadth 20 of T cell responses has been shown to reduce the opportunity for viral escape mutations to arise (17). It is this large breadth of potential epitopes, however, which renders the construct of large vectors frequently difficult and as well as being complicated by potential safety issues. Concerns have been raised about the potential ability of DNA vaccines to 25 integrate with host DNA, as well as the safety of viral vector vaccines in immunocompromised hosts. These represent the significant regulatory hurdles for these recombinant vaccines.

Also, despite significant advances towards understanding how T and linear B cell 30 epitopes are processed and presented to the immune system, the full potential of epitope-based vaccines has not been fully exploited. The main reason for this is the large number of different T cell epitopes, which must be identified for inclusion into such vaccines to

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cover the extreme human leucocyte antigen (HLA) polymorphism in the human population.

Infusion of whole antigen-pulsed or single epitope-pulsed cultured antigen presenting cells (APC) has previously been reported to be immunogenic in mouse models  
5 (22-27). However, other reports in inbred mouse models suggest the infusion of cells pulsed with single peptides may even be tolerogenic (induces a state of tolerance to the antigen which would be counterproductive for a vaccine) (28-31).

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## SUMMARY OF THE INVENTION

The present invention discloses the discovery that autologous cells, which have been contacted with overlapping peptides spanning a viral polypeptide antigen of interest produce a strong immunogenic response in an outbred population that protects against subsequent viral challenge. The present inventors propose that similar protective responses would be achieved using systemic administration of the overlapping peptides *per se*. The use of multiple overlapping peptides provides several advantages, including reducing the emergence of escape mutants and the facile production of peptide-based immunogenic compositions without prior knowledge of any epitopes. In this regard, the sequence overlap between peptides reduces or prevents loss of potential epitopes, which broadens the immunological coverage of the composition to cover potentially the diversity in the major histocompatibility complex across an outbred population.

Accordingly, in one aspect of the present invention, there is provided at least one set of peptides for modulating an immune response to one or more polypeptides of interest. Individual peptides of a respective set comprise different portions of an amino acid sequence corresponding to a single polypeptide of interest (e.g., particular pathogenic regions of a polypeptide), and display partial sequence identity or similarity to at least one other peptide of the same set of peptides. In certain embodiments, at least 2, 3, 4, 5, 6, 7 sets of peptides are employed, wherein peptide sequences in each set are derived from a distinct polypeptide of interest.

The partial sequence identity or similarity is typically contained at one or both ends of an individual peptide. Suitably, at one or both of these ends there are at least 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 contiguous amino acid residues whose sequence is identical or similar to an amino acid sequence contained within at least one other of the peptides.

In certain embodiments, the peptide is at least 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30 amino acid residues in length and suitably no more than about 500, 200, 100, 80, 60, 50, 40 amino acid residues in length. Suitably, the length of the peptides is selected to enhance the production of a cytolytic T lymphocyte response (e.g., peptides of about 8 to about 10 amino acids in length), or a T helper lymphocyte response (e.g., peptides of about 12 to about 20 amino acids in length).

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In certain embodiments, the peptide sequences are derived from at least about 30, 40, 50, 60, 70, 80 90, 91, 92, 93, 94, 95, 96, 97, 98, 99% of the sequence corresponding to the polypeptide of interest.

The polypeptide of interest is suitably an antigen selected from a protein antigen, 5 an antigen expressed by cancer cells, a particulate antigen, an alloantigen, an autoantigen or an allergen, or an immune complex. In certain embodiments, the polypeptide of interest is a disease- or condition-associated polypeptide such as but not limited to a polypeptide produced by a pathogenic organism or a cancer. Examples of pathogenic organisms include, but are not restricted to, yeast, viruses, bacteria, helminths, protozoans and 10 mycoplasmas. Examples of cancers include, but are not restricted to, melanoma, lung cancer, breast cancer, cervical cancer, prostate cancer, colon cancer, pancreatic cancer, stomach cancer, bladder cancer, kidney cancer, post transplant lymphoproliferative disease (PTLD), Hodgkin's Lymphoma and the like.

In another aspect, the invention provides antigen-presenting cells or their 15 precursors which have been contacted with a set of peptides as broadly described above for a time and under conditions sufficient for the peptides or processed forms thereof to be presented by the antigen-presenting cells or by their precursors.

In a related aspect, the invention provides a process for producing antigen-presenting cells for modulating an immune response to a polypeptide of interest. The 20 process generally comprises contacting antigen-presenting cells or their precursors with at least one set of peptides as broadly described above for a time and under conditions sufficient for the peptides or processed form thereof to be presented by the antigen-presenting cells or by their precursors. Suitably, when precursors are used, the precursors are cultured for a time and under conditions sufficient to differentiate antigen-presenting 25 cells from the precursors.

In some embodiments, the or each set of peptides is contacted with substantially purified antigen-presenting cells or their precursors. In other embodiments, the or each set of peptides is contacted with a heterogeneous population of antigen-presenting cells or their precursors. In these embodiments, the heterogenous pool of cells can be blood or 30 peripheral blood mononuclear cells. Typically, the antigen-presenting cells or their precursors are selected from monocytes, macrophages, cells of myeloid lineage, B cells, dendritic cells or Langerhans cells. In still other embodiments, the or each set of peptides is

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contacted with an uncultured population of antigen-presenting cells or their precursors. The population can be homogenous or heterogeneous, illustrative examples of which include whole blood, fresh blood, or fractions thereof such as, but not limited to, peripheral blood mononuclear cells, buffy coat fractions of whole blood, packed red cells, irradiated blood,  
5 dendritic cells, monocytes, macrophages, neutrophils, lymphocytes, natural killer cells and natural killer T cells.

The antigen-presenting cells broadly described above are also useful for producing lymphocytes, including T lymphocytes and B lymphocytes, for modulating an immune response to a specified antigen or group of antigens. Accordingly, in yet another  
10 aspect, the invention provides a method for producing antigen-specific lymphocytes. The method comprises contacting a population of lymphocytes, or their precursors, with an antigen-presenting cell as broadly described above for a time and under conditions sufficient to produce the antigen-specific lymphocytes that modulate an immune response to at least one polypeptide from which the overlapping peptides were derived.

15 In yet another aspect, the invention contemplates a composition comprising at least one set of peptides, or the antigen-presenting cells, or the lymphocytes, as broadly described above, and a pharmaceutically acceptable carrier and/or diluent. In certain embodiments, the composition may further comprise an adjuvant (e.g., compounds that stabilise the peptides or antigens against degradation by host enzymes).

20 In yet another aspect, the invention embraces a method for modulating an immune response to a polypeptide of interest, comprising administering to a patient in need of such treatment at least one set of peptides, or the antigen-presenting cells, or the lymphocytes, or the composition as broadly described above for a time and under conditions sufficient to modulate the immune response.

25 In a related aspect, the invention encompasses a method for treatment and/or prophylaxis of a disease or condition associated with the presence of a polypeptide of interest, comprising administering to a patient in need of such treatment or prophylaxis an effective amount of at least one set of peptides, or the antigen-presenting cells, or the lymphocytes, or the composition as broadly described above. In some embodiments, peptides or antigen-presenting cells or the lymphocytes are administered systemically, typically by injection.  
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In still yet another aspect, the invention contemplates the use of at least one set of peptides, or of the antigen-presenting cells, or of the lymphocytes, as broadly described above, in the preparation of a medicament for modulating an immune response to a polypeptide of interest or for treating or preventing a disease or condition associated with  
5 the presence of a polypeptide of interest.

The present invention also discloses the discovery that it is not necessary to culture a population of antigen-presenting cells or their precursors to expand that population prior to contacting it with a target antigen so that the contacted population is useful for modulating an immune response to the target antigen in a suitable recipient.  
10 Instead, the present inventors have unexpectedly discovered that uncultured antigen-presenting cells or their precursors, when contacted with an antigen that corresponds to a target antigen, are sufficient to modulate an immune response to the target antigen. The use of uncultured antigen-presenting cells or their precursors circumvents the need for expensive culturing and cell processing facilities and, in certain desirable embodiments,  
15 provides much faster vaccination regimens, as compared to current protocols.

Accordingly, in another aspect, the present invention features a composition of matter for modulating an immune response in a subject to a target antigen, the composition comprising uncultured antigen-presenting cells or their precursors, which have been contacted with an antigen corresponding to the target antigen for a time (e.g., from about 1  
20 minute to about 5 days) and under conditions sufficient to express a processed or modified form of the antigen for presentation to the subject's immune system (e.g., T lymphocytes). Illustrative examples of uncultured cells include whole blood, fresh blood, or fractions thereof such as but not limited to peripheral blood mononuclear cells, buffy coat fractions of whole blood, packed red cells, irradiated blood, dendritic cells, monocytes,  
25 macrophages, neutrophils, lymphocytes, natural killer cells and natural killer T cells. The antigen corresponding to the target antigen can be of any type including, for example, nucleic acids, peptides, hormones, whole protein antigens, cellular material (e.g., live or inactivated cancer cells), particulate matter such as, but not limited to, cell debris, apoptotic cells, lipid aggregates such as liposomes, membranous vehicles, microspheres,  
30 heat aggregated proteins, virosomes, virus-like particles and whole organisms including, for example, bacteria, mycobacteria, viruses, fungi, protozoa or parts thereof. In some embodiments, the antigen is selected from a proteinaceous molecule or a nucleic acid molecule. In some embodiments, the uncultured cells are contacted with at two or more

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antigens. In illustrative examples of this type, the antigens are in the form of overlapping or non-overlapping peptides or one or more polynucleotides from which the peptides are expressible.

In a related aspect, the invention extends to the use of uncultured antigen-presenting cells or their precursors in the preparation of a medicament for the treatment of a disease or condition in a subject, which disease or condition is associated with the presence or aberrant expression of a target antigen, wherein the antigen-presenting cells or their precursors have been contacted with an antigen that corresponds to the target antigen for a time and under conditions sufficient to express a processed or modified form of the antigen for presentation to the subject's immune system.

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## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagrammatic representation showing one embodiment of an SIV<sub>mac236</sub> gag peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 125 is 14 amino acids in length. The full-length gag sequence is modified from the HIV sequence database <http://hiv-web.lanl.gov>.

Figure 2 is a diagrammatic representation showing one embodiment of an SIV<sub>mac236</sub> pol peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. The full-length pol sequence is modified from the HIV sequence database <http://hiv-web.lanl.gov>.

Figure 3 is a diagrammatic representation showing one embodiment of an SIV<sub>mac236</sub> nef peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. The full-length nef sequence is modified from the HIV sequence database <http://hiv-web.lanl.gov>.

Figure 4 is a diagrammatic representation showing one embodiment of an SHIV<sub>SF162P3</sub> env peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 211 is 14 amino acids in length. \*Peptide overlaps preceding peptide by 10 amino acids to eliminate a forbidden Q n-terminal peptide. The full-length env sequence is modified from the HIV sequence database <http://hiv-web.lanl.gov>.

Figure 5 is a schematic representation of an *in vivo* CTL killing assay performed at weeks 10, 15 and 20.

Figure 6 is a graphical representation showing *in vivo* CTL killing of SIVgag overlapping peptide-pulsed cells. Two weeks after the FPV-boost (week 10), 3 equal PBMC populations were labelled with SNARF (2.5 μM) or CFSE (2.5 μM or 0.25 μM) and were pulsed with SIVpol, nef or gag overlapping peptide pools (OPAL), respectively. Blood sampled at 5 min, and at 4 and 16 h post-OPAL infusion was RBC-lysed and 10<sup>6</sup> lymphocyte events were acquired by flow cytometry. At 5 min, all 3 populations of labelled PBMC are of relatively equal numbers. By 4 and 16 hours, 2xDNA/FPV-

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immunised monkey H20 displayed 27.3% and 76.0% clearance of SIVgag-pulsed PBMC with respect to SIVnef-pulsed PBMC, respectively, whereas no SIVgag-specific killing was observed in control-immunised monkey E20. Note that less events were collected at 4 h than 16 h.

- 5       Figure 7 is a graphical representation showing vigorous killing of SIVgag- and SIVpol-pulsed PBMC following SHIV challenge. Two weeks after SHIV challenge (week 20), equal PBMC populations were labelled with SNARF (5 $\mu$ M) or CFSE (6 $\mu$ M or 2.5  $\mu$ M) and were pulsed with SIVpol, no peptide, or SIVgag overlapping peptide pools (OPAL), respectively. 10<sup>6</sup> RBC-lysed lymphocyte events were acquired by flow cytometry.
- 10      2xDNA/FPV-immunised monkeys H20 and H21, Displayed 92.3% and 98.3% killing of SIVgag-pulsed PBMC. These animals received 2 separate infusions of SIVpol- pulsed PBMC, furthermore displaying >99% SIVpol-specific killing. Previously CFSE-labelled PBMC were accounted for by flow cytometric analysis of 10<sup>6</sup> lymphocytes immediately prior to OPAL-infusion (not shown).
- 15      Figure 8 is a photographic representation showing a boost in T-cell immunogenicity 1 week following OPAL-infusion analysed by IFN $\gamma$  ELISpot. A boost in SIVgag and pol peptide pool responses is evident in 2xDNA/FPV-immunised monkey H21, where as a primed response to SIVpol peptide pool is detected in control-immunised monkey E20 (week 10 shown above).
- 20      Figure 9 is a graphical representation depicting INF $\gamma$  ELISpot analysis 1 week following OPAL infusion at week 10. A boost in T-cell immunogenicity to SIVgag, pol and nef overlapping peptide pools by OPAL infusion at week 10 was analysed 1 week later by ELISpot. Increased responses to SIVgag were detected in all four 2xDNA/FPV-immunised animals. Increased SIVpol responses were present in the 2xDNA/FPV-immunised monkeys, H20 and H21 (monkeys B00 and H8 did not receive any pol-pulsed PBMC), and in one control-immunised monkey, E20. No responses to SIVnef were primed in any animals. \*IFN $\gamma$  spots in monkeys E20 (prior to OPAL infusion) and B00 (post-OPAL infusion) were excluded due to ELISpot developmental problems.

- 30      Figure 10 is a graphical representation showing INF $\gamma$  ELISpot analysis 1 week following OPAL infusion at week 15. A boost in T-cell immunogenicity to SIVgag, pol, nef and HIV-1env overlapping peptide pools by OPAL infusion at week 15 was analysed 1 week later by INF $\gamma$  ELISpot. Increased responses to SIVgag were detected in all four

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2xDNA/FPV-immunised animals. SIVpol responses were marginally increased (or primed) in monkeys, E22, B00, H20 and H21. Increased responses to WI SIV were evident in all animals, whereas no responses were detected for SIVnef or HIV-env in any animals.

Figure 11 is a graphical representation depicting mean INF $\gamma$  ELISpot of immunogenicity of OPAL infusion. Mean INF $\gamma$  ELISpot responses to (A) SIVgag and (B) SIVpol overlapping peptide pool of control- and 2xDNA/FPV-immunised animals receiving OPAL infusions (bold) were compared to animals receiving equivalent immunisations but no OPAL infusions, before and after the OPAL infusions given at weeks 10 and 15 following the immunisation. For the comparison of SIVpol-specific responses, 2xDNA/FPV-immunised animals were grouped based on receiving either 1 (B00 and H8) or 2 (H20 and H21) doses of pol-OPAL infusions.

Figure 12 is a graphical representation showing the outcome of SHIV intrarectal challenge. At week 18 all control-and 2xDNA/FPV-immunised macaques were challenged intrarectally with SHIV<sub>mn229</sub> and were assessed for plasma SHIV RNA viral load and CD4+ T cell count over the course of the infection. Recipients of OPAL infusion were compared to their respective immunised non-OPAL recipients. Group comparisons indicate mean  $\pm$  SE. 2xDNA/FPV-immunised macaques receiving OPAL infusions were further grouped based on receiving either 1 or 2 separate doses of pol-pulsed PBMC (B00 & H8, and H20 & H21, respectively).

Figure 13 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Gag peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 124 is 12 amino acids in length. The full-length Gag sequence is modified from the HIV sequence database.

Figure 14 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Nef peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 49 is 14 amino acids in length. The full-length Nef sequence is modified from the HIV sequence database.

Figure 15 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Pol peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically,

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indicated in brackets left of the peptide sequence. Peptide 248 is 14 amino acids in length. The full-length Pol sequence is modified from the HIV sequence database HIV-1.

Figure 16 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Rev peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 27 is 13 amino acids in length. The full-length Rev sequence is modified from the HIV sequence database.

Figure 17 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Tat peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 24 is 14 amino acids in length. The full-length Tat sequence is modified from the HIV sequence database.

Figure 18 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Vif peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 46 is 12 amino acids in length. The full-length Vif sequence is modified from the HIV sequence database.

Figure 19 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Vpr peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 22 is 12 amino acids in length. The full-length Vpr sequence is modified from the HIV sequence database.

Figure 20 is a diagrammatic representation showing one embodiment of an HIV-1 consensus B clade Vpu peptide pool sequence. Each peptide is 15 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide 18 is 13 amino acids in length. The full-length Vpu sequence is modified from the HIV sequence database.

Figure 21 is a diagrammatic representation showing one embodiment of a peptide pool sequence of HCV 1a H77. Each peptide is 18 amino acids in length and overlaps the preceding peptide by 11 amino acids. Peptides are numbered periodically, indicated in brackets left of the peptide sequence. Peptide couples 25 & 26, 153 & 154, 220 & 221, 239 & 240, 242 & 243, 244 & 245, 345 & 346 are divided into 15- and 14-mers due to

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problematic sequences of the original 18-mer peptide. The full-length HCV 1a H77 sequence is modified from the HCV sequence database.

Figure 22 is a graphical representation depicting induction of CD4+ and CD8+ T cell responses to SHIV antigens in monkeys infected with SHIV utilising administration of whole blood pulsed with overlapping 15mer peptides encompassing the open reading frames of the entire SHIV genome. The whole blood pulsed peptides were administered at weeks 0, 4 and 8 (arrows) and a boost in T cell immunogenicity of both CD4+ and CD8+ T cells measured by IFNgamma production to SHIV antigens gag, pol and env detected by ICS is seen following each time point. \*Pre-OPAL T cells responses measured 1 week prior to 1<sup>st</sup> OPAL (week -1).

Figure 23 is a graphical representation depicting *de novo* induction of CD4+ and CD8+ T cell responses to HCV in monkeys utilising administration of whole blood pulsed with overlapping 18mer peptides encompassing the open reading frames of the entire HCV type-1a H77 genome. The whole blood pulsed peptides were administered at weeks 0, 4 and 8 (arrows) in two separate pools (peptides: 1-116, and; 117-441). Induction and boosting of T cell immunogenicity of both CD4+ and CD8+ T cells measured by IFNgamma production to HCV antigens detected by ICS is seen following each time point. \*Pre-OPAL T cells responses measured 1 week prior to 1<sup>st</sup> OPAL (week -1).

Figure 24 is a graphical representation showing *de novo* induction of CD4+ and CD8+ T cell responses to peptides representative of drug-resistant mutations in HIV-1 described in HIV-1 infected humans, in monkeys utilising administration of whole blood pulsed with 17mer peptides encompassing known sites of reverse transcriptase or protease resistance mutations. The whole blood pulsed peptides were administered at weeks 0, 4 and 8 (arrows). Induction and boosting of T cell immunogenicity of both CD4+ and CD8+ T cells measured by IFNgamma production to HIV-1 drug-resistant mutation peptides detected by ICS is seen following each time point. \*Pre-OPAL T cells responses measured 1 week prior to 1<sup>st</sup> OPAL (week -1).

Figure 25 is a diagrammatic representation showing one embodiment of a pool of single peptides corresponding to drug-resistant mutations in the reverse transcriptase region or the protease region of wild-type HIV-1 described in HIV-1 humans (Mimotopes, Melbourne). 17mer peptides were designed spanning the sites of common known mutations to incorporate the resistant mutation at the 9<sup>th</sup> amino acid residue (bold) on each

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17mer peptide, such that every 9mer epitope (the most common length of CD8+ T cell epitopes) as a result of proteolytic cleaving *ex vivo* would encompass the mutation.

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## DETAILED DESCRIPTION OF THE INVENTION

### 1. Definitions

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by those of ordinary skill in the art to which the invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, preferred methods and materials are described. For the purposes of the present invention, the following terms are defined below.

The articles “*a*” and “*an*” are used herein to refer to one or to more than one (*i.e.*, to at least one) of the grammatical object of the article. By way of example, “*an element*” means one element or more than one element.

The term “*about*” is used herein to refer to conditions (e.g., amounts, concentrations, time etc) that vary by as much as 30%, preferably by as much as 20%, and more preferably by as much as 10% to a specified condition.

By “*antigen*” is meant all, or part of, a protein, peptide, or other molecule or macromolecule capable of eliciting an immune response in a vertebrate animal, preferably a mammal. Such antigens are also reactive with antibodies from animals immunised with said protein, peptide, or other molecule or macromolecule.

By “*antigen-binding molecule*” is meant a molecule that has binding affinity for a target antigen. It will be understood that this term extends to immunoglobulins, immunoglobulin fragments and non-immunoglobulin derived protein frameworks that exhibit antigen-binding activity.

By “*autologous*” is meant something (e.g., cells, tissues etc) derived from the same organism.

The term “*allogeneic*” as used herein refers to cells, tissues, organisms etc that are of different genetic constitution.

Throughout this specification, unless the context requires otherwise, the words “*comprise*”, “*comprises*” and “*comprising*” will be understood to imply the inclusion of a stated step or element or group of steps or elements but not the exclusion of any other step or element or group of steps or elements.

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By "*corresponds to*" or "*corresponding to*" is meant a polynucleotide (a) having a nucleotide sequence that is substantially identical or complementary to all or a portion of a reference polynucleotide sequence or (b) encoding an amino acid sequence identical to an amino acid sequence in a peptide or protein. This phrase also includes within its scope a peptide or polypeptide having an amino acid sequence that is substantially identical or similar to a sequence of amino acids in a reference peptide or protein.

As used herein, the terms "*culturing*", "*culture*" and the like refer to the set of procedures used *in vitro* where a population of cells (or a single cell) is incubated under conditions which have been shown to support the growth or maintenance of the cells *in vitro*. The art recognises a wide number of formats, media, temperature ranges, gas concentrations etc. which need to be defined in a culture system. The parameters will vary based on the format selected and the specific needs of the individual who practices the methods herein disclosed. However, it is recognised that the determination of culture parameters is routine in nature.

By "*effective amount*", in the context of modulating an immune response or treating or preventing a disease or condition, is meant the administration of that amount of composition to an individual in need thereof, either in a single dose or as part of a series, that is effective for that modulation, treatment or prevention. The effective amount will vary depending upon the health and physical condition of the individual to be treated, the taxonomic group of individual to be treated, the formulation of the composition, the assessment of the medical situation, and other relevant factors. It is expected that the amount will fall in a relatively broad range that can be determined through routine trials.

By "*expression vector*" is meant any autonomous genetic element capable of directing the synthesis of a protein encoded by the vector. Such expression vectors are known by practitioners in the art.

The term "*gene*" as used herein refers to any and all discrete coding regions of the cell's genome, as well as associated non-coding and regulatory regions. The gene is also intended to mean the open reading frame encoding specific polypeptides, introns, and adjacent 5' and 3' non-coding nucleotide sequences involved in the regulation of expression. In this regard, the gene may further comprise control signals such as promoters, enhancers, termination and/or polyadenylation signals that are naturally associated with a given gene, or heterologous control signals. The DNA sequences may be

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cDNA or genomic DNA or a fragment thereof. The gene may be introduced into an appropriate vector for extrachromosomal maintenance or for integration into the host.

A compound or composition is "*immunogenic*" if it is capable of either: a) generating an immune response against an antigen (e.g., a tumour antigen) in a naive individual; or b) reconstituting, boosting, or maintaining an immune response in an individual beyond what would occur if the compound or composition was not administered. A compound or composition is immunogenic if it is capable of attaining either of these criteria when administered in single or multiple doses.

Reference herein to "*immuno-interactive*" includes reference to any interaction, reaction, or other form of association between molecules and in particular where one of the molecules is, or mimics, a component of the immune system.

By "*isolated*" is meant material that is substantially or essentially free from components that normally accompany it in its native state.

By "*modulating*" is meant increasing or decreasing, either directly or indirectly, the immune response of an individual. In certain embodiments, "*modulation*" or "*modulating*" means that a desired/selected response is more efficient (e.g., at least 10%, 20%, 30%, 40%, 50%, 60% or more), more rapid (e.g., at least 10%, 20%, 30%, 40%, 50%, 60% or more), greater in magnitude (e.g., at least 10%, 20%, 30%, 40%, 50%, 60% or more), and/or more easily induced (e.g., at least 10%, 20%, 30%, 40%, 50%, 60% or more) than in the absence of an antigen or than if the antigen had been used alone.

The term "*operably connected*" or "*operably linked*" as used herein means placing a structural gene under the regulatory control of a promoter, which then controls the transcription and optionally translation of the gene. In the construction of heterologous promoter/structural gene combinations, it is generally preferred to position the genetic sequence or promoter at a distance from the gene transcription start site that is approximately the same as the distance between that genetic sequence or promoter and the gene it controls in its natural setting; *i.e.* the gene from which the genetic sequence or promoter is derived. As is known in the art, some variation in this distance can be accommodated without loss of function. Similarly, the preferred positioning of a regulatory sequence element with respect to a heterologous gene to be placed under its control is defined by the positioning of the element in its natural setting; *i.e.* the genes from which it is derived.

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The terms "*patient*," "*subject*" and "*individual*" are used interchangeably herein to refer to any subject, particularly a vertebrate subject, and even more particularly a mammalian subject, for whom therapy or prophylaxis is desired. However, it will be understood that these terms do not imply that symptoms are present. Suitable vertebrate animals that fall within the scope of the invention include, but are not restricted to, primates, livestock animals (e.g., sheep, cows, horses, donkeys, pigs), laboratory test animals (e.g., rabbits, mice, rats, guinea pigs, hamsters), companion animals (e.g., cats, dogs) and captive wild animals (e.g., foxes, deer, dingoes, reptiles, avians, fish).

By "*pharmaceutically-acceptable carrier*" is meant a solid or liquid filler, diluent or encapsulating substance that may be safely used in topical or systemic administration.

The term "*polynucleotide*" or "*nucleic acid*" as used herein designates mRNA, RNA, cRNA, cDNA or DNA. The term typically refers to oligonucleotides greater than 30 nucleotides in length.

"*Polypeptide*", "*peptide*" and "*protein*" are used interchangeably herein to refer to a polymer of amino acid residues and to variants and synthetic analogues of the same. Thus, these terms apply to amino acid polymers in which one or more amino acid residues is a synthetic non-naturally occurring amino acid, such as a chemical analogue of a corresponding naturally occurring amino acid, as well as to naturally-occurring amino acid polymers.

Reference herein to a "*promoter*" is to be taken in its broadest context and includes the transcriptional regulatory sequences of a classical genomic gene, including the TATA box which is required for accurate transcription initiation, with or without a CCAAT box sequence and additional regulatory elements (i.e. upstream activating sequences, enhancers and silencers) which alter gene expression in response to developmental and/or environmental stimuli, or in a tissue-specific or cell-type-specific manner. A promoter is usually, but not necessarily, positioned upstream or 5' of a structural gene, the expression of which it regulates. Furthermore, the regulatory elements comprising a promoter are usually positioned within 2 kb of the start site of transcription of the gene. Preferred promoters according to the invention may contain additional copies of one or more specific regulatory elements to further enhance expression in a cell, and/or to alter the timing of expression of a structural gene to which it is operably connected.

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The term "*purified peptide*" means that the peptide is substantially free of cellular material or other contaminating proteins from the cell or tissue source from which the peptide is derived, or substantially free from chemical precursors or other chemicals when chemically synthesised. "Substantially free" means that a preparation of a peptide of the invention is at least 10% pure. In certain embodiments, the preparation of peptide has less than about 30%, 25%, 20%, 15%, 10% and desirably 5% (by dry weight), of non-peptide protein (also referred to herein as a "contaminating protein"), or of chemical precursors or non-peptide chemicals. The invention includes isolated or purified preparations of at least 0.01, 0.1, 1.0, and 10 milligrams in dry weight.

5        The term "*recombinant polynucleotide*" as used herein refers to a polynucleotide formed *in vitro* by the manipulation of nucleic acid into a form not normally found in nature. For example, the recombinant polynucleotide may be in the form of an expression vector. Generally, such expression vectors include transcriptional and translational regulatory nucleic acid operably linked to the nucleotide sequence.

10      By "*recombinant polypeptide*" is meant a polypeptide made using recombinant techniques, *i.e.*, through the expression of a recombinant polynucleotide.

15      By "*reporter molecule*" as used in the present specification is meant a molecule that, by its chemical nature, provides an analytically identifiable signal that allows the detection of a complex comprising an antigen-binding molecule and its target antigen. The 20 term "*reporter molecule*" also extends to use of cell agglutination or inhibition of agglutination such as red blood cells on latex beads, and the like.

25      The term "*sequence identity*" as used herein refers to the extent that sequences are identical on a nucleotide-by-nucleotide basis or an amino acid-by-amino acid basis over a window of comparison. Thus, a "*percentage of sequence identity*" is calculated by comparing two optimally aligned sequences over the window of comparison, determining the number of positions at which the identical nucleic acid base (e.g., A, T, C, G, I) or the identical amino acid residue (e.g., Ala, Pro, Ser, Thr, Gly, Val, Leu, Ile, Phe, Tyr, Trp, Lys, Arg, His, Asp, Glu, Asn, Gln, Cys and Met) occurs in both sequences to yield the number of matched positions, dividing the number of matched positions by the total number of 30 positions in the window of comparison (*i.e.*, the window size), and multiplying the result by 100 to yield the percentage of sequence identity. For the purposes of the present invention, "*sequence identity*" will be understood to mean the "match percentage"

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calculated by the DNASIS computer program (Version 2.5 for windows; available from Hitachi Software engineering Co., Ltd., South San Francisco, California, USA) using standard defaults as used in the reference manual accompanying the software.

"Similarity" refers to the percentage number of amino acids that are identical or 5 constitute conservative substitutions as defined in Table B *infra*. Similarity may be determined using sequence comparison programs such as GAP (Deveraux *et al.* 1984, *Nucleic Acids Research* 12, 387-395). In this way, sequences of a similar or substantially different length to those cited herein might be compared by insertion of gaps into the alignment, such gaps being determined, for example, by the comparison algorithm used by 10 GAP.

Terms used to describe sequence relationships between two or more polynucleotides or polypeptides include "reference sequence", "comparison window", "sequence identity", "percentage of sequence identity" and "substantial identity". A "reference sequence" is at least 12 but frequently 15 to 18 and often at least 25 monomer 15 units, inclusive of nucleotides and amino acid residues, in length. Because two polynucleotides may each comprise (1) a sequence (*i.e.*, only a portion of the complete polynucleotide sequence) that is similar between the two polynucleotides, and (2) a sequence that is divergent between the two polynucleotides, sequence comparisons between two (or more) polynucleotides are typically performed by comparing sequences of 20 the two polynucleotides over a "comparison window" to identify and compare local regions of sequence similarity. A "comparison window" refers to a conceptual segment of at least 6 contiguous positions, usually about 50 to about 100, more usually about 100 to about 150 in which a sequence is compared to a reference sequence of the same number of contiguous positions after the two sequences are optimally aligned. The comparison 25 window may comprise additions or deletions (*i.e.*, gaps) of about 20% or less as compared to the reference sequence (which does not comprise additions or deletions) for optimal alignment of the two sequences. Optimal alignment of sequences for aligning a comparison window may be conducted by computerised implementations of algorithms (GAP, BESTFIT, FASTA, and TFASTA in the Wisconsin Genetics Software Package Release 30 7.0, Genetics Computer Group, 575 Science Drive Madison, WI, USA) or by inspection and the best alignment (*i.e.*, resulting in the highest percentage homology over the comparison window) generated by any of the various methods selected. Reference also may be made to the BLAST family of programs as for example disclosed by Altschul *et*

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al., 1997, *Nucl. Acids Res.* 25:3389. A detailed discussion of sequence analysis can be found in Unit 19.3 of Ausubel *et al.*, "Current Protocols in Molecular Biology", John Wiley & Sons Inc, 1994-1998, Chapter 15.

5 By "*substantially purified population*" and the like is meant that greater than about 80%, usually greater than about 90%, more usually greater than about 95%, typically greater than about 98%, and more typically greater than about 99% of the cells in the population are antigen-presenting cells of a chosen type.

10 The term "*uncultured*" as used herein refers to a population of cells (or a single cell), which have been removed from an animal and incubated or processed under conditions that do not result in the growth or expansion of the cells *in vitro*, or that result in negligible growth or expansion of the cells (e.g., an increase of less than about 50%, 40%, 30%, 20%, 15%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.5%, 0.2% or 0.1% in cell number as compared to the number of cells at the commencement of the incubation or processing). In certain desirable embodiments, the population of cells (or the single cell) is 15 incubated or processed under conditions supporting the maintenance of the cells *in vitro*.

20 By "*vector*" is meant a nucleic acid molecule, preferably a DNA molecule derived, for example, from a plasmid, bacteriophage, or plant virus, into which a nucleic acid sequence may be inserted or cloned. A vector preferably contains one or more unique restriction sites and may be capable of autonomous replication in a defined host cell including a target cell or tissue or a progenitor cell or tissue thereof, or be integrable with the genome of the defined host such that the cloned sequence is reproducible. Accordingly, the vector may be an autonomously replicating vector, *i.e.*, a vector that exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication, e.g., a linear or closed circular plasmid, an extrachromosomal element, a 25 minichromosome, or an artificial chromosome. The vector may contain any means for assuring self-replication. Alternatively, the vector may be one which, when introduced into the host cell, is integrated into the genome and replicated together with the chromosome(s) into which it has been integrated. A vector system may comprise a single vector or plasmid, two or more vectors or plasmids, which together contain the total DNA to be 30 introduced into the genome of the host cell, or a transposon. The choice of the vector will typically depend on the compatibility of the vector with the host cell into which the vector is to be introduced. The vector may also include a selection marker such as an antibiotic resistance gene that can be used for selection of suitable transformants.

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## 2. *Immunomodulating sets of overlapping peptides*

The present invention is predicated in part on the discovery that antigen-presenting cells contacted *ex vivo* with a set of overlapping peptides spanning a viral polypeptide antigen of interest (also referred to herein as Overlapping Peptide-pulsed Autologous ceLls, OPAL) are effective in producing a strong immunogenic response in an outbred population, without prior knowledge of the epitopes of the antigen. Since antigen-presenting cells form a significant part of the circulatory system, it is proposed that systemic delivery of the overlapping peptides *per se* will produce a similar protective effect. Accordingly, the present invention broadly provides a set of peptides for modulating an immune response to a polypeptide of interest, wherein individual peptides comprise different portions of an amino acid sequence corresponding to the polypeptide of interest and display partial sequence identity or similarity to at least one other peptide of the set.

The partial sequence identity or similarity is typically contained at one or both ends of an individual peptide. In one embodiment, there are at least 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 40, 50 contiguous amino acid residues at one or both ends of an individual peptide, whose sequence is identical or similar to an amino acid sequence contained within at least one other of the peptides. In an alternate embodiment, there are less than 500, 100, 50, 40, 30 contiguous amino acid residues at one or both ends of an individual peptide, whose sequence is identical or similar to an amino acid sequence contained within at least one other of the peptides. Such 'sequence overlap' is advantageous to prevent or otherwise reduce the loss of any potential epitopes contained within a polypeptide of interest. In specific examples disclosed herein, the sequence overlap is 11 amino acid residues.

Typically, when peptides have partial sequence similarity, their sequences will usually differ by one or more conserved and/or non-conserved amino acid substitutions. Exemplary conservative substitutions are listed in the following table.

**TABLE A**

<i>Original Residue</i>	<i>Exemplary Substitutions</i>	<i>Original Residue</i>	<i>Exemplary Substitutions</i>
Ala	Ser	Leu	Ile, Val
Arg	Lys	Lys	Arg, Gln, Glu

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<i>Original Residue</i>	<i>Exemplary Substitutions</i>	<i>Original Residue</i>	<i>Exemplary Substitutions</i>
Asn	Gln, His	Met	Leu, Ile,
Asp	Glu	Phe	Met, Leu, Tyr
Cys	Ser	Ser	Thr
Gln	Asn	Thr	Ser
Glu	Asp	Trp	Tyr
Gly	Pro	Tyr	Trp, Phe
His	Asn, Gln	Val	Ile, Leu
Ile	Leu, Val		

Conserved or non-conserved substitutions may correspond to polymorphisms in a polypeptide of interest. Polymorphic polypeptides are expressed by various pathogenic organisms and cancers. For example, the polymorphic polypeptides may be expressed by different viral strains or clades or by different cancers in distinct individuals. Thus, where polymorphic regions of a pathogen of interest are involved, it is generally desirable to use additional sets of peptides covering the variation in amino acid residue at the polymorphic site.

The peptides of the invention may be of any suitable size that can be utilised to elicit an immune response to a polypeptide of interest. A number of factors can influence the choice of peptide size. For example, the size of a peptide can be chosen such that it includes, or corresponds to the size of, CD4+ T cell epitopes, CD8+ T cell epitopes and/or B cell epitopes, and their processing requirements. Practitioners in the art will recognise that class I-restricted CD8+ T cell epitopes are typically between 8 and 10 amino acid residues in length and if placed next to unnatural flanking residues, such epitopes can generally require 2 to 3 natural flanking amino acid residues to ensure that they are efficiently processed and presented. Class II-restricted CD4+ T cell epitopes usually range between 12 and 25 amino acid residues in length and may not require natural flanking residues for efficient proteolytic processing although it is believed that natural flanking residues may play a role. Another important feature of class II-restricted epitopes is that they generally contain a core of 9-10 amino acid residues in the middle which bind

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specifically to class II MHC molecules with flanking sequences either side of this core stabilising binding by associating with conserved structures on either side of class II MHC antigens in a sequence independent manner. Thus the functional region of class II-restricted epitopes is typically less than about 15 amino acid residues long. The size of

5 linear B cell epitopes and the factors effecting their processing, like class II-restricted epitopes, are quite variable although such epitopes are frequently smaller in size than 15 amino acid residues. From the foregoing, it is advantageous, but not essential, that the size of the peptide is at least 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30 amino acid residues. Suitably, the size of the peptide is no more than about 500, 200, 100, 80, 60, 50, 40 amino  
10 residues. In one embodiment, the size of the peptide is large enough to minimise loss of T cell and/or B cell epitopes. In another embodiment, the size of the peptide is sufficient for presentation by an antigen-presenting cell of a T cell and/or a B cell epitope contained within the peptide. In one example of this embodiment, the size of the peptide is about 15 amino acid residues.

15 The polypeptide of interest is suitably a disease- or condition-associated antigen, which may be selected from endogenous antigens produced by an individual or exogenous antigens that are foreign to the individual. Suitable endogenous antigens include, but are not restricted to, self-antigens that are targets of autoimmune responses as well as cancer or tumour antigens. Illustrative examples of self antigens useful in the treatment or prevention  
20 of autoimmune disorders include, but not limited to, diabetes mellitus, arthritis (including rheumatoid arthritis, juvenile rheumatoid arthritis, osteoarthritis, psoriatic arthritis), multiple sclerosis, myasthenia gravis, systemic lupus erythematosus, autoimmune thyroiditis, dermatitis (including atopic dermatitis and eczematous dermatitis), psoriasis, Sjögren's Syndrome, including keratoconjunctivitis sicca secondary to Sjögren's  
25 Syndrome, alopecia areata, allergic responses due to arthropod bite reactions, Crohn's disease, ulcer, iritis, conjunctivitis, keratoconjunctivitis, ulcerative colitis, asthma, allergic asthma, cutaneous lupus erythematosus, scleroderma, vaginitis, proctitis, drug eruptions, leprosy reversal reactions, erythema nodosum leprosum, autoimmune uveitis, allergic encephalomyelitis, acute necrotizing haemorrhagic encephalopathy, idiopathic  
30 bilateral progressive sensorineural hearing loss, aplastic anaemia, pure red cell anaemia, idiopathic thrombocytopenia, polychondritis, Wegener's granulomatosis, chronic active hepatitis, Stevens-Johnson syndrome, idiopathic sprue, lichen planus, Graves ophthalmopathy, sarcoidosis, primary biliary cirrhosis, uveitis posterior, and interstitial

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lung fibrosis. Other autoantigens include those derived from nucleosomes for the treatment of systemic lupus erythematosus (e.g., GenBank Accession No. D28394; Bruggen et al., 1996, *Ann. Med. Interne* (Paris), 147:485-489) and from the 44,000 Da peptide component of ocular tissue cross-reactive with *O. volvulus* antigen (McKeelme 5 et al., 1993, *Ann Trop. Med. Parasitol.* 87:649-652). Thus, illustrative autoantigens antigens that can be used in the compositions and methods of the present invention include, but are not limited to, at least a portion of a lupus autoantigen, Smith, Ro, La, U1-RNP, fibrillin (scleroderma), pancreatic  $\beta$  cell antigens, GAD65 (diabetes related), insulin, myelin basic protein, myelin proteolipid protein, histones, PLP, collagen, glucose-6-phosphate isomerase, citrullinated proteins and peptides, thyroid antigens, thyroglobulin, thyroid-stimulating hormone (TSH) receptor, various tRNA synthetases, components of the acetyl choline receptor (AchR), MOG, proteinase-3, myeloperoxidase, epidermal cadherin, acetyl choline receptor, platelet antigens, nucleic acids, nucleic acid:protein complexes, joint antigens, antigens of the nervous system, salivary gland proteins, skin 10 antigens, kidney antigens, heart antigens, lung antigens, eye antigens, erythrocyte antigens, liver antigens and stomach antigens.

15

Non-limiting examples of cancer or tumour antigens include antigens from a cancer or tumour selected from ABL1 protooncogene, AIDS Related Cancers, Acoustic Neuroma, Acute Lymphocytic Leukaemia, Acute Myeloid Leukaemia, Adenocystic carcinoma, Adrenocortical Cancer, Agnogenic myeloid metaplasia, Alopecia, Alveolar soft-part sarcoma, Anal cancer, Angiosarcoma, Aplastic Anaemia, Astrocytoma, Ataxiatelangiectasia, Basal Cell Carcinoma (Skin), Bladder Cancer, Bone Cancers, Bowel cancer, Brain Stem Glioma, Brain and CNS Tumours, Breast Cancer, CNS tumours, Carcinoid Tumours, Cervical Cancer, Childhood Brain Tumours, Childhood Cancer, Childhood 20 Leukaemia, Childhood Soft Tissue Sarcoma, Chondrosarcoma, Choriocarcinoma, Chronic Lymphocytic Leukaemia, Chronic Myeloid Leukaemia, Colorectal Cancers, Cutaneous T-Cell Lymphoma, Dermatofibrosarcoma-protuberans, Desmoplastic-Small-Round-Cell-Tumour, Ductal Carcinoma, Endocrine Cancers, Endometrial Cancer, Ependymoma, Esophageal Cancer, Ewing's Sarcoma, Extra-Hepatic Bile Duct Cancer, Eye Cancer, Eye: 25 Melanoma, Retinoblastoma, Fallopian Tube cancer, Fanconi Anaemia, Fibrosarcoma, Gall Bladder Cancer, Gastric Cancer, Gastrointestinal Cancers, Gastrointestinal-Carcinoid-Tumour, Genitourinary Cancers, Germ Cell Tumours, Gestational-Trophoblastic-Disease, Glioma, Gynaecological Cancers, Haematological Malignancies, Hairy Cell Leukaemia,

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Head and Neck Cancer, Hepatocellular Cancer, Hereditary Breast Cancer, Histiocytosis, Hodgkin's Disease, Human Papillomavirus, Hydatidiform mole, Hypercalcemia, Hypopharynx Cancer, IntraOcular Melanoma, Islet cell cancer, Kaposi's sarcoma, Kidney Cancer, Langerhan's-Cell-Histiocytosis, Laryngeal Cancer, Leiomyosarcoma, Leukaemia,  
5 Li-Fraumeni Syndrome, Lip Cancer, Liposarcoma, Liver Cancer, Lung Cancer, Lymphedema, Lymphoma, Hodgkin's Lymphoma, Non-Hodgkin's Lymphoma, Male Breast Cancer, Malignant-Rhabdoid-Tumour-of-Kidney, Medulloblastoma, Melanoma, Merkel Cell Cancer, Mesothelioma, Metastatic Cancer, Mouth Cancer, Multiple Endocrine Neoplasia, Mycosis Fungoides, Myelodysplastic Syndromes, Myeloma, Myeloproliferative  
10 Disorders, Nasal Cancer, Nasopharyngeal Cancer, Nephroblastoma, Neuroblastoma, Neurofibromatosis, Nijmegen Breakage Syndrome, Non-Melanoma Skin Cancer, Non-Small-Cell-Lung-Cancer-(NSCLC), Ocular Cancers, Oesophageal Cancer, Oral cavity Cancer, Oropharynx Cancer, Osteosarcoma, Ostomy Ovarian Cancer, Pancreas Cancer, Paranasal Cancer, Parathyroid Cancer, Parotid Gland Cancer, Penile Cancer, Peripheral-  
15 Neuroectodermal-Tumours, Pituitary Cancer, Polycythemia vera, Prostate Cancer, Rare-cancers-and-associated-disorders, Renal Cell Carcinoma, Retinoblastoma, Rhabdomyosarcoma, Rothmund-Thomson Syndrome, Salivary Gland Cancer, Sarcoma, Schwannoma, Sezary syndrome, Skin Cancer, Small Cell Lung Cancer (SCLC), Small Intestine Cancer, Soft Tissue Sarcoma, Spinal Cord Tumours, Squamous-Cell-Carcinoma-  
20 (skin), Stomach Cancer, Synovial sarcoma, Testicular Cancer, Thymus Cancer, Thyroid Cancer, Transitional-Cell-Cancer-(bladder), Transitional-Cell-Cancer-(renal-pelvis/-ureter), Trophoblastic Cancer, Urethral Cancer, Urinary System Cancer, Uroplakins, Uterine sarcoma, Uterus Cancer, Vaginal Cancer, Vulva Cancer, Waldenstrom's-Macroglobulinemia, Wilms' Tumour. In certain embodiments, the cancer or tumour relates  
25 to melanoma. Illustrative examples of melanoma-related antigens include melanocyte differentiation antigen (e.g., gp100, MART, TRP-1, Tyros, TRP2, MC1R, MUC1F, MUC1R or a combination thereof) and melanoma-specific antigens (e.g., BAGE, GAGE-1, gp100In4, MAGE-1 (e.g., GenBank Accession No. X54156 and AA494311), MAGE-3, MAGE4, PRAME, TRP2IN2, NYNSO1a, NYNSO1b, LAGE1, p97 melanoma antigen  
30 (e.g., GenBank Accession No. M12154) or a combination thereof). Other tumour-specific antigens include the Ras peptide and p53 peptide associated with advanced cancers, MUC1-KLH antigen associated with breast carcinoma (e.g., GenBank Accession No. J03651), CEA (carcinoembryonic antigen) associated with colorectal cancer (e.g., GenBank Accession No. X98311), gp100 (e.g., GenBank Accession No. S73003) and the

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PSA antigen with prostate cancer (e.g., GenBank Accession No. X14810). The p53 gene sequence is known (See e.g., Harris *et al.*, 1986 *Mol. Cell. Biol.* 6:4650-4656) and is deposited with GenBank under Accession No. M14694.

5 Foreign antigens are suitably selected from transplantation antigens, allergens as well as antigens from pathogenic organisms. Transplantation antigens can be derived from donor cells or tissues from e.g., heart, lung, liver, pancreas, kidney, neural graft components, or from the donor antigen-presenting cells bearing MHC loaded with self antigen in the absence of exogenous antigen.

10 Non-limiting examples of allergens include Fel d 1 (i.e., the feline skin and salivary gland allergen of the domestic cat *Felis domesticus*, the amino acid sequence of which is disclosed International Publication WO 91/06571), Der p I, Der p II, Der fI or Der fII (i.e., the major protein allergens from the house dust mite *dermatophagoides*, the amino acid sequence of which is disclosed in International Publication WO 94/24281). Other allergens may be derived, for example from the following: grass, tree and weed (including 15 ragweed) pollens; fungi and moulds; foods such as fish, shellfish, crab, lobster, peanuts, nuts, wheat gluten, eggs and milk; stinging insects such as bee, wasp, and hornet and the chironomidae (non-biting midges); other insects such as the housefly, fruitfly, sheep blow fly, screw worm fly, grain weevil, silkworm, honeybee, non-biting midge larvae, bee moth larvae, mealworm, cockroach and larvae of *Tenibrio molitor* beetle; spiders and mites, 20 including the house dust mite; allergens found in the dander, urine, saliva, blood or other bodily fluid of mammals such as cat, dog, cow, pig, sheep, horse, rabbit, rat, guinea pig, mouse and gerbil; airborne particulates in general; latex; and protein detergent additives.

Exemplary pathogenic organisms include, but are not limited to, viruses, bacteria, fungi parasites, algae and protozoa and amoebae. Illustrative examples of viruses include 25 viruses responsible for diseases including, but not limited to, measles, mumps, rubella, poliomyelitis, hepatitis A, B (e.g., GenBank Accession No. E02707), and C (e.g., GenBank Accession No. E06890), as well as other hepatitis viruses, influenza, adenovirus (e.g., types 4 and 7), rabies (e.g., GenBank Accession No. M34678), yellow fever, Epstein-Barr virus and other herpesviruses such as papillomavirus, Ebola virus, 30 influenza virus, Japanese encephalitis (e.g., GenBank Accession No. E07883), dengue (e.g., GenBank Accession No. M24444), hantavirus, sendai virus, respiratory syncytial virus, orthomyxoviruses, vesicular stomatitis virus, visna virus, cytomegalovirus and human immunodeficiency virus (HIV) (e.g., GenBank Accession No. U18552). Any

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suitable antigen derived from such viruses are useful in the practice of the present invention. For example, illustrative retroviral antigens derived from HIV include, but are not limited to, antigens such as gene products of the *gag*, *pol*, and *env* genes, the Nef protein, reverse transcriptase, and other HIV components. Illustrative examples of hepatitis viral antigens include, but are not limited to, antigens such as the S, M, and L proteins of hepatitis B virus, the pre-S antigen of hepatitis B virus, and other hepatitis, e.g., hepatitis A, B, and C, viral components such as hepatitis C viral RNA. Illustrative examples of influenza viral antigens include; but are not limited to, antigens such as hemagglutinin and neuraminidase and other influenza viral components. Illustrative examples of measles viral antigens include, but are not limited to, antigens such as the measles virus fusion protein and other measles virus components. Illustrative examples of rubella viral antigens include, but are not limited to, antigens such as proteins E1 and E2 and other rubella virus components; rotaviral antigens such as VP7sc and other rotaviral components. Illustrative examples of cytomegaloviral antigens include, but are not limited to, antigens such as envelope glycoprotein B and other cytomegaloviral antigen components. Non-limiting examples of respiratory syncytial viral antigens include antigens such as the RSV fusion protein, the M2 protein and other respiratory syncytial viral antigen components. Illustrative examples of herpes simplex viral antigens include, but are not limited to, antigens such as immediate early proteins, glycoprotein D, and other herpes simplex viral antigen components. Non-limiting examples of varicella zoster viral antigens include antigens such as 9PI, gpII, and other varicella zoster viral antigen components. Non-limiting examples of Japanese encephalitis viral antigens include antigens such as proteins E, M-E, M-E-NS 1, NS 1, NS 1-NS2A, 80%E, and other Japanese encephalitis viral antigen components. Illustrative examples of rabies viral antigens include, but are not limited to, antigens such as rabies glycoprotein, rabies nucleoprotein and other rabies viral antigen components. Illustrative examples of papillomavirus antigens include, but are not limited to, the L1 and L2 capsid proteins as well as the E6/E7 antigens associated with cervical cancers, See Fundamental Virology, Second Edition, eds. Fields, B.N. and Knipe, D.M., 1991, Raven Press, New York, for additional examples of viral antigens.

Illustrative examples of fungi include *Acremonium* spp., *Aspergillus* spp., *Basidiobolus* spp., *Bipolaris* spp., *Blastomyces dermatidis*, *Candida* spp., *Cladophialophora carrionii*, *Coccidioides immitis*, *Conidiobolus* spp., *Cryptococcus* spp.,

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5       *Curvularia* spp., *Epidermophyton* spp., *Exophiala jeanselmei*, *Exserohilum* spp.,  
*Fonsecaea compacta*, *Fonsecaea pedrosoi*, *Fusarium oxysporum*, *Fusarium solani*,  
*Geotrichum candidum*, *Histoplasma capsulatum* var. *capsulatum*, *Histoplasma capsulatum*  
var. *duboisii*, *Hortaea werneckii*, *Lacazia loboi*, *Lasiodiplodia theobromae*, *Leptosphaeria*  
*senegalensis*, *Madurella grisea*, *Madurella mycetomatis*, *Malassezia furfur*, *Microsporum*  
spp., *Neotestudina rosatii*, *Onychocola canadensis*, *Paracoccidioides brasiliensis*,  
*Phialophora verrucosa*, *Piedraia hortae*, *Piedra iahortae*, *Pityriasis versicolor*,  
*Pseudallesheria boydii*, *Pyrenophaeta romeroi*, *Rhizopus arrhizus*, *Scopulariopsis*  
*brevicaulis*, *Scytalidium dimidiatum*, *Sporothrix schenckii*, *Trichophyton* spp.,  
10      *Trichosporon* spp., Zygomycete fungi, *Absidia corymbifera*, *Rhizomucor pusillus* and  
*Rhizopus arrhizus*. Thus, illustrative fungal antigens that can be used in the compositions  
and methods of the present invention include, but are not limited to, candida fungal  
antigen components; histoplasma fungal antigens such as heat shock protein 60 (HSP60)  
15      and other histoplasma fungal antigen components; cryptococcal fungal antigens such as  
capsular polysaccharides and other cryptococcal fungal antigen components; coccidioides  
fungal antigens such as spherule antigens and other coccidioides fungal antigen  
components; and tinea fungal antigens such as trichophytin and other coccidioides fungal  
antigen components.

20      Illustrative examples of bacteria include bacteria that are responsible for diseases  
including, but not restricted to, diphtheria (e.g., *Corynebacterium diphtheriae*), pertussis  
(e.g., *Bordetella pertussis*, GenBank Accession No. M35274), tetanus (e.g., *Clostridium*  
*tetani*, GenBank Accession No. M64353), tuberculosis (e.g., *Mycobacterium*  
*tuberculosis*), bacterial pneumonias (e.g., *Haemophilus influenzae*), cholera (e.g., *Vibrio*  
*cholerae*), anthrax (e.g., *Bacillus anthracis*), typhoid, plague, shigellosis (e.g., *Shigella*  
25      *dysenteriae*), botulism (e.g., *Clostridium botulinum*), salmonellosis (e.g., GenBank  
Accession No. L03833), peptic ulcers (e.g., *Helicobacter pylori*), Legionnaire's Disease,  
Lyme disease (e.g., GenBank Accession No. U59487). Other pathogenic bacteria include  
*Escherichia coli*, *Clostridium perfringens*, *Pseudomonas aeruginosa*, *Staphylococcus*  
*aureus* and *Streptococcus pyogenes*. Thus, bacterial antigens which can be used in the  
compositions and methods of the invention include, but are not limited to: pertussis  
bacterial antigens such as pertussis toxin, filamentous hemagglutinin, pertactin, F M2,  
FIM3, adenylate cyclase and other pertussis bacterial antigen components; diphtheria  
bacterial antigens such as diphtheria toxin or toxoid and other diphtheria bacterial

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antigen components; tetanus bacterial antigens such as tetanus toxin or toxoid and other tetanus bacterial antigen components, streptococcal bacterial antigens such as M proteins and other streptococcal bacterial antigen components; gram-negative bacilli bacterial antigens such as lipopolysaccharides and other gram-negative bacterial antigen components; *Mycobacterium tuberculosis* bacterial antigens such as mycolic acid, heat shock protein 65 (HSP65), the 30kDa major secreted protein, antigen 85A and other mycobacterial antigen components; *Helicobacter pylori* bacterial antigen components, pneumococcal bacterial antigens such as pneumolysin, pneumococcal capsular polysaccharides and other pneumococcal bacterial antigen components; *Haemophilus influenza* bacterial antigens such as capsular polysaccharides and other *Haemophilus influenza* bacterial antigen components; anthrax bacterial antigens such as anthrax protective antigen and other anthrax bacterial antigen components; rickettsiae bacterial antigens such as rmpA and other rickettsiae bacterial antigen component. Also included with the bacterial antigens described herein are any other bacterial, mycobacterial, mycoplasmal, rickettsial, or chlamydial antigens.

Illustrative examples of protozoa include protozoa that are responsible for diseases including, but not limited to, malaria (e.g., GenBank Accession No. X53832), hookworm, onchocerciasis (e.g., GenBank Accession No. M27807), schistosomiasis (e.g., GenBank Accession No. LOS 198), toxoplasmosis, trypanosomiasis, leishmaniasis, giardiasis (GenBank Accession No. M33641), amoebiasis, filariasis (e.g., GenBank Accession No. J03266), borreliosis, and trichinosis. Thus, protozoal antigens which can be used in the compositions and methods of the invention include, but are not limited to: plasmodium falciparum antigens such as merozoite surface antigens, sporozoite surface antigens, circumsporozoite antigens, gametocyte/gamete surface antigens, blood-stage antigen pf 155/RESA and other plasmodial antigen components; toxoplasma antigens such as SAG-1, p30 and other toxoplasmal antigen components; schistosomae antigens such as glutathione-S-transferase, paramyosin, and other schistosomal antigen components; leishmania major and other leishmaniae antigens such as gp63, lipophosphoglycan and its associated protein and other leishmanial antigen components; and trypanosoma cruzi antigens such as the 75-77kDa antigen, the 56kDa antigen and other trypanosomal antigen components.

The present invention also contemplates toxin components as antigens. Illustrative examples of toxins include, but are not restricted to, staphylococcal

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enterotoxins, toxic shock syndrome toxin; retroviral antigens (*e.g.*, antigens derived from HIV), streptococcal antigens, staphylococcal enterotoxin-A (SEA), staphylococcal enterotoxin-B (SEB), staphylococcal enterotoxin<sub>1-3</sub> (SE<sub>1-3</sub>), staphylococcal enterotoxin-D (SED), staphylococcal enterotoxin-E (SEE) as well as toxins derived from mycoplasma,  
5 mycobacterium, and herpes viruses.

In one example of the present invention, the size of individual peptides is about 14 or 15 amino acid residues and the sequence overlap at one or both ends of an individual peptide is about 11 amino acid residues. However, it will be understood that other suitable peptide sizes and sequence overlap sizes are contemplated by the present invention, which  
10 can be readily ascertained by persons of skill in the art.

It is advantageous but not necessary to utilise the entire sequence of a polypeptide of interest for producing a set of overlapping peptides. Typically, at least 30%, 40%, 50%, 60%, 70%, 80% 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% of the sequence corresponding to a polypeptide of interest is used to produce the overlapping peptides of  
15 the invention. However, it will be understood that the more sequence information from a polypeptide of interest that is utilised to produce the overlapping peptides, the greater the outbred population coverage will be of the overlapping peptides as an immunogen. Suitably, no sequence information from the polypeptide of interest is excluded (*e.g.*, because of an apparent lack of immunological epitopes, since more rare or subdominant  
20 epitopes may be inadvertently missed). If required, hypervariable sequences within a polypeptide of interest can be either excluded from the construction of an overlapping set of peptides, or additional sets of peptides covering the polymorphic regions can be constructed and administered. Peptide sequences may include additional sequences that are not derived from a polypeptide of interest. These additional sequences may have various  
25 functions, including improving solubility, stability or immunogenicity or facilitating purification. Typically, such additional sequences are contained at one or both ends of a respective peptide.

Persons of skill in the art will appreciate that when preparing a set of overlapping peptides according to the invention, it may be advantageous to use sequence information from a plurality of different polypeptides produced by a pathogenic organism or expressed in a cancer. Accordingly, in certain embodiments, at least 2, 3, 4, 5, 6, 7, 9, 10, 15, 20 other sets of peptides are used for the production of the immunomodulating compositions of the invention, wherein the sequences of a respective other set of peptides are derived from a  
30

- distinct polypeptide of interest and wherein individual peptides of the respective other set display partial sequence identity or similarity to at least one other peptide of a corresponding set of peptides. It is advantageous in this respect to utilise as many polypeptides as possible from, or in relation to, a particular source in the construction of sets of overlapping peptides. Suitably, at least about 30%, 40%, 50%, 60%, 70%, 80% 5 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, and desirably 100%, of the polypeptides expressed by the source is used in the construction of the corresponding sets of overlapping peptides. Exemplary viral polypeptides that can be used for such construction include, but are not restricted to, latent polypeptides, regulatory polypeptides 10 or polypeptides expressed early during their replication cycle. Suitably, polypeptides from a protozoan, bacterium, mycoplasma, fungus or helminth include, but are not restricted to, secretory polypeptides, regulatory polypeptides and polypeptides expressed on the surface of these organisms. Polypeptides from a cancer or tumour, which can be used for the construction of overlapping peptide sets, are suitably cancer-specific polypeptides.
- 15 Representative overlapping peptide sets for modulating the immune response to simian immunodeficiency virus (SIV) and/or the chimeric SIV-HIV-1 (SHIV), both of which are known to be suitable models for the pathogenic HIV-1 virus in humans, can be based on one or more polypeptides selected from SIV gag, pol, nef or SHIV env as for example presented in Figures 1 to 4. Exemplary overlapping peptide sets for modulating 20 the immune response to HIV-1 can be based on one or more polypeptides selected from HIV Gag, Nef, Pol, Rev, Tat, Vif, Vpr and Vpu as for example set forth in Figures 13 to 20. Exemplary overlapping peptide sets for modulating the immune response to HCV 1a can be based on the HCV 1a H77 polyprotein sequence as for example set forth in Figure 21.
- 25 The overlapping peptide sets of the invention may be prepared by any suitable procedure known to those of skill in the art. For example, the peptide sets can be synthesised conveniently using solution synthesis or solid phase synthesis as described, for example, in Chapter 9 of Atherton and Shephard (1989, Solid Phase Peptide Synthesis: A Practical Approach. IRL Press, Oxford) and in Roberge *et al* (1995, *Science* 269: 202). 30 Syntheses may employ, for example, either *t*-butyloxycarbonyl (*t*-Boc) or 9-fluorenylmethyloxycarbonyl (Fmoc) chemistries (see Chapter 9.1, of Coligan *et al.*, CURRENT PROTOCOLS IN PROTEIN SCIENCE, John Wiley & Sons, Inc. 1995-1997; Stewart and Young, 1984, Solid Phase Peptide Synthesis, 2nd ed. Pierce Chemical Co.,

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Rockford, Ill; and Atherton and Shephard, *supra*). In specific embodiments, the individual peptides are solubilized in DMSO (e.g., 100% pure DMSO) at high concentration (1 mg peptide/10-30 µL DMSO) so that large pools of peptides do not contain excessive amounts of DMSO when pulsed onto cells.

- 5        Alternatively, individual peptides may be prepared by a procedure including the steps of: (a) preparing a synthetic construct including a synthetic polynucleotide encoding an individual peptide or an overlapping set of peptides, wherein the synthetic polynucleotide is operably linked to a regulatory polynucleotide; (b) introducing the synthetic construct into a suitable host cell; (c) culturing the host cell to express the synthetic polynucleotide; and (d) isolating the individual peptide. The synthetic construct is preferably in the form of an expression vector. For example, the expression vector can be a self-replicating extra-chromosomal vector such as a plasmid, or a vector that integrates into a host genome. Typically, the regulatory polynucleotide includes, but is not limited to, promoter sequences, leader or signal sequences, ribosomal binding sites, transcriptional 10 start and stop sequences, translational start and termination sequences, and enhancer or activator sequences. Constitutive or inducible promoters as known in the art are contemplated by the invention. The promoters may be either naturally occurring promoters, or hybrid promoters that combine elements of more than one promoter. The regulatory polynucleotide will generally be appropriate for the host cell used for expression. Numerous types of appropriate expression vectors and suitable regulatory 15 polynucleotides are known in the art for a variety of host cells. In certain embodiments, the expression vector contains a selectable marker gene to allow the selection of transformed host cells. Selection genes are well known in the art and will vary with the host cell used. In other embodiments, the expression vector also includes a nucleic acid sequence that 20 codes for a fusion partner so that an individual peptide is expressed as a fusion polypeptide with the fusion partner. The main advantage of fusion partners is that they assist identification and/or purification of the fusion polypeptide. Exemplary fusion partners include, but are not limited to, glutathione-S-transferase (GST), Fc portion of human IgG, maltose binding protein (MBP) and hexahistidine (HIS<sub>6</sub>), which are particularly useful for 25 isolation of the fusion polypeptide by affinity chromatography. For the purposes of fusion polypeptide purification by affinity chromatography, relevant matrices for affinity chromatography are glutathione-, amylose-, and nickel- or cobalt-conjugated resins respectively. Many such matrices are available in "kit" form, such as the QIAexpress™ 30

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system (Qiagen) useful with (HIS<sub>6</sub>) fusion partners and the Pharmacia GST purification system. In a preferred embodiment, the recombinant polynucleotide is expressed in the commercial vector pFLAG™. Advantageously, the fusion partners also have protease cleavage sites, such as for Factor X<sub>a</sub>, Thrombin and inteins (protein introns), which allow the relevant protease to partially digest the fusion polypeptide of the invention and thereby liberate the recombinant polypeptide of the invention therefrom. The liberated peptide can then be isolated from the fusion partner by subsequent chromatographic separation. Fusion partners according to the invention also include within their scope "epitope tags", which are usually short peptide sequences for which a specific antibody is available. Well known examples of epitope tags for which specific monoclonal antibodies are readily available include c-Myc, influenza virus, haemagglutinin and FLAG tags.

The step of introducing the synthetic construct into the host cell may be achieved using any suitable technique including transfection, and transformation, the choice of which will be dependent on the host cell employed. Such methods are well known to those of skill in the art. The peptides of the invention may be produced by culturing a host cell transformed with the synthetic construct. The conditions appropriate for protein expression will vary with the choice of expression vector and the host cell. This is easily ascertained by one skilled in the art through routine experimentation. Suitable host cells for expression may be prokaryotic or eukaryotic. One preferred host cell for expression of a polypeptide according to the invention is a bacterium. The bacterium used may be *Escherichia coli*. Alternatively, the host cell may be an insect cell such as, for example, SF9 cells that may be utilised with a baculovirus expression system.

The amino acids of the peptides can be any non-naturally occurring or any naturally occurring amino acid. Examples of unnatural amino acids and derivatives during peptide synthesis include but are not limited to, use of 4-amino butyric acid, 6-aminohexanoic acid, 4-amino-3-hydroxy-5-phenylpentanoic acid, 4-amino-3-hydroxy-6-methylheptanoic acid, t-butylglycine, norleucine, norvaline, phenylglycine, ornithine, sarcosine, 2-thienyl alanine and/or D-isomers of amino acids. A list of unnatural amino acids contemplated by the present invention is shown in TABLE B.

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**TABLE B**

<i>Non-conventional amino acid</i>	<i>Non-conventional amino acid</i>
$\alpha$ -aminobutyric acid	L-N-methylalanine
$\alpha$ -amino- $\alpha$ -methylbutyrate	L-N-methylarginine
aminocyclopropane-carboxylate	L-N-methyleasparagine
aminoisobutyric acid	L-N-methyleaspartic acid
aminonorbornyl-carboxylate	L-N-methylcysteine
cyclohexylalanine	L-N-methylglutamine
cyclopentylalanine	L-N-methylglutamic acid
L-N-methylisoleucine	L-N-methylhistidine
D-alanine	L-N-methylleucine
D-arginine	L-N-methyllysine
D-aspartic acid	L-N-methylmethionine
D-cysteine	L-N-methylnorleucine
D-glutamate	L-N-methylnorvaline
D-glutamic acid	L-N-methylornithine
D-histidine	L-N-methylphenylalanine
D-isoleucine	L-N-methylproline
D-leucine	L-N-medlylserine
D-lysine	L-N-methylthreonine
D-methionine	L-N-methyltryptophan
D-ornithine	L-N-methyltyrosine
D-phenylalanine	L-N-methylvaline
D-proline	L-N-methylethylglycine
D-serine	L-N-methyl-t-butylglycine
D-threonine	L-norleucine
D-tryptophan	L-norvaline

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<i>Non-conventional amino acid</i>	<i>Non-conventional amino acid</i>
D-tyrosine	$\alpha$ -methyl-aminoisobutyrate
D-valine	$\alpha$ -methyl- $\gamma$ -aminobutyrate
D- $\alpha$ -methylalanine	$\alpha$ -methylcyclohexylalanine
D- $\alpha$ -methylarginine	$\alpha$ -methylcyclopentylalanine
D- $\alpha$ -methylasparagine	$\alpha$ -methyl- $\alpha$ -naphthylalanine
D- $\alpha$ -methylaspartate	$\alpha$ -methylpenicillamine
D- $\alpha$ -methylcysteine	N-(4-aminobutyl)glycine
D- $\alpha$ -methylglutamine	N-(2-aminoethyl)glycine
D- $\alpha$ -methylhistidine	N-(3-aminopropyl)glycine
D- $\alpha$ -methylisoleucine	N-amino- $\alpha$ -methylbutyrate
D- $\alpha$ -methyleucine	$\alpha$ -naphthylalanine
D- $\alpha$ -methyllysine	N-benzylglycine
D- $\alpha$ -methylmethionine	N-(2-carbamylediyl)glycine
D- $\alpha$ -methylornithine	N-(carbamylmethyl)glycine
D- $\alpha$ -methylphenylalanine	N-(2-carboxyethyl)glycine
D- $\alpha$ -methylproline	N-(carboxymethyl)glycine
D- $\alpha$ -methylserine	N-cyclobutylglycine
D- $\alpha$ -methylthreonine	N-cycloheptylglycine
D- $\alpha$ -methyltryptophan	N-cyclohexylglycine
D- $\alpha$ -methyltyrosine	N-cyclodecylglycine
L- $\alpha$ -methyleucine	L- $\alpha$ -methyllysine
L- $\alpha$ -methylmethionine	L- $\alpha$ -methylnorleucine
L- $\alpha$ -methylnorvaline	L- $\alpha$ -methylornithine
L- $\alpha$ -methylphenylalanine	L- $\alpha$ -methylproline
L- $\alpha$ -methylserine	L- $\alpha$ -methylthreonine

<i>Non-conventional amino acid</i>	<i>Non-conventional amino acid</i>
L- $\alpha$ -methyltryptophan	L- $\alpha$ -methyltyrosine
L- $\alpha$ -methylvaline	L-N-methylhomophenylalanine
N-(N-(2,2-diphenylethyl carbamylmethyl)glycine	N-(N-(3,3-diphenylpropyl carbamylmethyl)glycine
1-carboxy-1-(2,2-diphenyl-ethyl amino)cyclopropane	

The invention also contemplates modifying the peptides of the invention using ordinary molecular biological techniques so as to alter their resistance to proteolytic degradation or to optimise solubility properties or to render them more suitable as an immunogenic agent.

### 3. *Antigen-presenting cell embodiments*

The present invention also discloses the discovery that antigen-presenting cells which have been contacted with overlapping peptide sets as described in Section 2 are potent modulators of immune responses and are especially useful for raising strong immunogenic responses that can prevent or ameliorate the symptoms of a disease or condition of interest. Accordingly, the invention provides a process for producing antigen-specific antigen-presenting cells, comprising contacting antigen-presenting cells or their precursors with one or more sets of peptides as broadly described above for a time and under conditions sufficient for the peptides or processed forms thereof to be presented by the antigen-presenting cells or their precursors, and in the case of precursors, culturing the precursors for a time and under conditions sufficient to differentiate antigen-presenting cells from the precursors.

The present inventors have also found unexpectedly that, in contrast to current dogma, it is not necessary to culture purified antigen-presenting cells to increase their number before loading them with antigen for effective modulation of an immune response to the antigen in a recipient of those cells. Instead, the present inventors have discovered that an uncultured population of antigen-presenting cells or their precursors, when contacted with an antigen that corresponds to a target antigen of interest is sufficient to effectively modulate an immune response to the target antigen in a recipient of the contacted population. Accordingly, in another aspect, the present invention provides a

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process for producing antigen-specific antigen-presenting cells, comprising contacting an uncultured population of antigen-presenting cells or their precursors with an antigen corresponding to the target antigen for a time and under conditions sufficient for the antigen-presenting cells or their precursors to express a processed or modified form of the antigen. Illustrative examples of the uncultured population of antigen-presenting cells include whole blood, fresh blood, or fractions thereof such as but not limited to peripheral blood mononuclear cells (PMBC), buffy coat fractions of whole blood, packed red cells, irradiated blood, dendritic cells, monocytes, macrophages, neutrophils, lymphocytes, natural killer cells and natural killer T cells. In specific embodiments, the uncultured population of antigen-presenting cells is selected from freshly isolated blood or PMBC. According to this aspect of the present invention, the antigen used to contact the population is not limited to the overlapping set of peptides described in Section 2 above but instead encompasses antigens of any biological type including, for example, simple intermediary metabolites, sugars, lipids, and hormones as well as macromolecules such as complex carbohydrates, phospholipids, nucleic acid molecules and proteinaceous molecules. In illustrative examples, the antigen corresponding to the target antigen is selected from whole protein antigens, cellular material (e.g., live or inactivated cancer cells), particulate matter such as, but not limited to, cell debris, apoptotic cells, lipid aggregates such as liposomes, membranous vehicles, microspheres, heat aggregated proteins, virosomes, virus-like particles and whole organisms including, for example, bacteria, mycobacteria, viruses, fungi, protozoa or parts thereof.

Target antigens may be selected from endogenous antigens produced by a host or exogenous antigens that are foreign to the host, as described for example in Section 2. In certain embodiments, the antigen corresponding to the target antigen is a proteinaceous antigen. Such antigens may be isolated from a natural source or may be prepared by recombinant techniques as known in the art. Alternatively, crude antigen preparations can be produced by isolating a sample of a cell population or tissue for which a modified immune response is desired, and either lysing the sample or subjecting the sample to conditions that will lead to the formation of apoptotic cells (e.g., irradiation with ultra violet or with gamma rays, viral infection, cytokines or by depriving cells of nutrients in the cell culture medium, incubation with hydrogen peroxide, or with drugs such as dexamethasone, ceramide chemotherapeutics and anti-hormonal agents such as Lupron or Tamoxifen). The lysate or the apoptotic cells can then be used as a source of crude antigen

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for use in soluble form or for contact with antigen-presenting cells as described in more detail below.

### 3.1 Sources of antigen-presenting cells

The antigen-presenting cells suitably encompass both professional and facultative types of antigen-presenting cells. For example, professional antigen-presenting cells include, but are not limited to, macrophages, monocytes, cells of myeloid lineage, including monocytic-granulocytic-DC precursors, marginal zone Kupffer cells, microglia, T cells, B cells Langerhans cells and dendritic cells including interdigitating dendritic cells and follicular dendritic cells. Examples of facultative antigen-presenting cells include but are not limited to activated T cells, astrocytes, follicular cells, endothelium and fibroblasts. In a preferred embodiment, the antigen-presenting cells are selected from monocytes, macrophages, cells of myeloid lineage, dendritic cells or Langerhans cells.

Antigen-presenting cells or their precursors can be isolated by methods known to those of skill in the art. The source of antigen-presenting cell or precursor may differ depending upon the antigen-presenting cell required for modulating a specified immune response. In this context, the antigen-presenting cell can be selected from dendritic cells, macrophages, monocytes and other cells of myeloid lineage. Typically, precursors of antigen-presenting cells can be isolated from any tissue, but are most easily isolated from blood, cord blood or bone marrow (Sorg *et al.*, 2001, *Exp Hematol* 29: 1289-1294; Zheng *et al.*, 2000, *J Hematother Stem Cell Res* 9: 453-464). It is also possible to obtain suitable precursors from diseased tissues such as rheumatoid synovial tissue or fluid following biopsy or joint tap (Thomas *et al.*, 1994, *J Immunol* 152: 2613-2623; Thomas *et al.*, 1994, *J Immunol* 153: 4016-4028). Other examples include, but are not limited to liver, spleen, heart, kidney, gut and tonsil (Lu *et al.*, 1994, *Transplantation* 64: 1808-1815; McIlroy *et al.*, 2001, *Blood* 97: 3470-3477; Vremec *et al.*, 2000, *J Immunol* 164: 2978-2986; Hart and Fabre, 1981, *J Exp Med* 154(2): 347-361; Hart and McKenzie, 1988, *J Exp Med* 168(1): 157-170; Pavli *et al.*, 1990, *Immunology* 70(1): 40-47).

Leukocytes isolated directly from tissue provide a major source of antigen-presenting cell precursors. Typically, these precursors can only differentiate into antigen-presenting cells by culturing in the presence or absence of various growth factors *ex vivo* for at least about 6-9 days. However, in some advantageous embodiments of the present invention, antigen-presenting cells or their precursors (*e.g.*, in the form of freshly isolated

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blood or PMBC) are simply isolated from an individual and incubated in the presence of antigen and preferably one or more growth factors for much shorter periods, e.g., less than about 48, 36, 24, 12, 8, 7, 6, 5, 4, 3 or 2 hours or even less than about 60, 50, 40, 30, 20, 15, 10, 9, 8, 7, 6, 5, 4, 3 or 2 minutes, to produce antigen-specific antigen-presenting cells that  
5 are effective in raising an immunogenic response to that antigen.

In some embodiments, antigen-presenting cell precursors may be differentiated from crude mixtures or from partially or substantially purified preparations of precursors. Leukocytes can be conveniently purified from blood or bone marrow by density gradient centrifugation using, for example, Ficoll Hypaque which eliminates neutrophils and red  
10 cells (peripheral blood mononuclear cells or PBMCs), or by ammonium chloride lysis of red cells (leukocytes or white blood cells). Many precursors of antigen-presenting cells are present in peripheral blood as non-proliferating monocytes, which can be differentiated into specific antigen-presenting cells, including macrophages and dendritic cells, suitably by incubating the precursor in the presence of one or more specific cytokines.  
15

Tissue-derived precursors such as precursors of tissue dendritic cells or of Langerhans cells are typically obtained by mincing tissue (e.g., basal layer of epidermis) and digesting it with collagenase or dispase followed by density gradient separation, or selection of precursors based on their expression of cell surface markers. For example, Langerhans cell precursors express CD1 molecules as well as HLA-DR and can be purified  
20 on this basis.

In one embodiment, the antigen-presenting cell precursor is a precursor of macrophages. Generally these precursors can be obtained from monocytes of any source and can be differentiated into macrophages by prolonged incubation in the presence of medium and macrophage colony stimulating factor (M-CSF) (Erickson-Miller *et al.*, 1990,  
25 *Int J Cell Cloning* 8: 346-356; Metcalf and Burgess, 1982, *J Cell Physiol* 111: 275-283).

In another embodiment, the antigen presenting cell precursor is a precursor of Langerhans cells. Usually, Langerhans cells can be generated from human monocytes or CD34<sup>+</sup> bone marrow precursors in the presence of granulocyte/macrophage colony-stimulating factor (GM-CSF), IL-4/TNF $\alpha$  and TGF $\beta$  (Geissmann *et al.*, 1998, *J Exp Med* 187: 961-966; Strobl *et al.*, 1997, *Blood* 90: 1425-1434 Strobl *et al.*, 1997, *Adv Exp Med Biol* 417: 161-165; Strobl *et al.*, 1996, *J Immunol* 157: 1499-1507).

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In one embodiment, the antigen-presenting cell precursor is a precursor of dendritic cells. Several potential dendritic cell precursors can be obtained from peripheral blood, cord blood or bone marrow. These include monocytes, CD34<sup>+</sup> stem cells, granulocytes, CD33<sup>+</sup>CD11c<sup>+</sup> DC precursors, and committed myeloid progenitors – described below.

**Monocytes.** Monocytes can be purified by adherence to plastic for 1-2 h in the presence of tissue culture medium (e.g., RPMI) and serum (e.g., human or foetal calf serum), or in serum-free medium (Anton *et al.*, 1998, *Scand J Immunol* 47: 116-121.; Araki *et al.*, 2001, *Br J Haematol* 114: 681-689; Mackensen *et al.*, 2000, *Int J Cancer* 86: 385-392; Nestle *et al.*, 1998, *Nat Med* 4: 328-332; Romani *et al.*, 1996, *J Immunol Meth* 196: 137-151; Thurner *et al.*, 1999, *J Immunol Methods* 223: 1-15). Monocytes can also be elutriated from peripheral blood (Garderet *et al.*, 2001, *J Hematother Stem Cell Res* 10: 553-567). Monocytes can also be purified by immunoaffinity techniques, including immunomagnetic selection, flow cytometric sorting or panning (Araki *et al.*, 2001, *supra*; Battye and Shortman, 1991, *Curr. Opin. Immunol.* 3: 238-241), with anti-CD14 antibodies to obtain CD14<sup>hi</sup> cells. The numbers (and therefore yield) of circulating monocytes can be enhanced by the *in vivo* use of various cytokines including GM-CSF (Groopman *et al.*, 1987, *N Engl J Med* 317: 593-598; Hill *et al.*, 1995, *J Leukoc Biol* 58: 634-642). Monocytes can be differentiated into dendritic cells by prolonged incubation in the presence of GM-CSF and IL-4 (Romani *et al.*, 1994, *J Exp Med* 180: 83-93; Romani *et al.*, 1996, *supra*). A combination of GM-CSF and IL-4 at a concentration of each at between about 200 to about 2000 U/mL, more preferably between about 500 to about 1000 U/mL and even more preferably between about 800 U/mL (GM-CSF) and 1000 U/mL (IL-4) produces significant quantities of immature dendritic cells, *i.e.*, antigen-capturing phagocytic dendritic cells. Other cytokines which promote differentiation of monocytes into antigen-capturing phagocytic dendritic cells include, for example, IL-13.

**CD34<sup>+</sup> stem cells.** Dendritic cells can also be generated from CD34<sup>+</sup> bone marrow derived precursors in the presence of GM-CSF, TNF $\alpha$  ± stem cell factor (SCF, c-kitL), or GM-CSF, IL-4 ± flt3L (Bai *et al.*, 2002, *Int J Oncol* 20: 247-53; Chen *et al.*, 2001, *Clin Immunol* 98: 280-292; Loudovaris *et al.*, 2001, *J Hematother Stem Cell Res* 10: 569-578). CD34<sup>+</sup> cells can be derived from a bone marrow aspirate or from blood and can be enriched as for monocytes using, for example, immunomagnetic selection or immunocolumns (Davis *et al.*, 1994, *J Immunol Meth* 175: 247-257). The proportion of

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CD34<sup>+</sup> cells in blood can be enhanced by the *in vivo* use of various cytokines including (most commonly) G-CSF, but also flt3L and progenipoietin (Fleming *et al.*, 2001, *Exp Hematol* 29: 943-951; Pulendran *et al.*, 2000, *J Immunol* 165: 566-572; Robinson *et al.*, 2000, *J Hematother Stem Cell Res* 9: 711-720).

5       **Other myeloid progenitors.** DC can be generated from committed early myeloid progenitors in a similar fashion to CD34<sup>+</sup> stem cells, in the presence of GM-CSF and IL-4/TNF. Such myeloid precursors infiltrate many tissues in inflammation, including rheumatoid arthritis synovial fluid (Santiago-Schwarz *et al.*, 2001, *J Immunol* 167(3): 1758-68). Expansion of total body myeloid cells including circulating dendritic cell precursors and monocytes, can be achieved with certain cytokines, including flt-3 ligand, granulocyte colony-stimulating factor (G-CSF) or progenipoietin (pro-GP) (Fleming *et al.*, 2001, *supra*; Pulendran *et al.*, 2000, *supra*; Robinson *et al.*, 2000, *supra*). Administration of such cytokines for several days to a human or other mammal would enable much larger numbers of precursors to be derived from peripheral blood or bone marrow for *in vitro* manipulation. Dendritic cells can also be generated from peripheral blood neutrophil precursors in the presence of GM-CSF, IL-4 and TNF $\alpha$  (Kelly *et al.*, 2001, *Cell Mol Biol* (Noisy-le-grand) 47(1): 43-54; Oehler *et al.*, 1998, *J Exp Med* 187(7):1019-28). It should be noted that dendritic cells can also be generated, using similar methods, from acute myeloid leukemia cells (Oehler *et al.*, 2000, *Ann Hematol* 79(7): 355-62).

20      **Tissue DC precursors and other sources of APC precursors.** Other methods for DC generation exist from, for example, thymic precursors in the presence of IL-3 +/- GM-CSF, and liver DC precursors in the presence of GM-CSF and a collagen matrix. Transformed or immortalised dendritic cell lines may be produced using oncogenes such as *v-myc* as for example described by (Paglia *et al.*, 1993, *J Exp Med* 178(6): 1893-901) or by myb (Banyer and Hapel, 1999, *J Leukoc Biol* 66(2): 217-223; Gonda *et al.*, 1993, *Blood* 82(9): 2813-2822).

30      **Circulating DC precursors.** These have been described in human and mouse peripheral blood. One can also take advantage of particular cell surface markers for identifying suitable dendritic cell precursors. Specifically, various populations of dendritic cell precursors can be identified in blood by the expression of CD11c and the absence or low expression of CD14, CD19, CD56 and CD3 (O'Doherty *et al.*, 1994, *Immunology* 82: 487-493; O'Doherty *et al.*, 1993, *J Exp Med* 178: 1067-1078). These cells can also be identified by the cell surface markers CD13 and CD33 (Thomas *et al.*, 1993, *J Immunol*

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151(12): 6840-6852). A second subset, which lacks CD14, CD19, CD56 and CD3, known as plasmacytoid dendritic cell precursors, does not express CD11c, but does express CD123 (IL-3R chain) and HLA-DR (Farkas *et al.*, 2001, *Am J Pathol* 159: 237-243; Grouard *et al.*, 1997, *J Exp Med* 185: 1101-1111; Rissoan *et al.*, 1999, *Science* 283: 1183-5 1186). Most circulating CD11c<sup>+</sup> dendritic cell precursors are HLA-DR<sup>+</sup>, however some precursors may be HLA-DR-. The lack of MHC class II expression has been clearly demonstrated for peripheral blood dendritic cell precursors (del Hoyo *et al.*, 2002, *Nature* 415: 1043-1047).

10 Optionally, CD33<sup>+</sup>CD14<sup>-lo</sup> or CD11c<sup>+</sup>HLA-DR<sup>+</sup>, lineage marker-negative dendritic cell precursors described above can be differentiated into more mature antigen-presenting cells by incubation for 18-36 h in culture medium or in monocyte conditioned medium (Thomas *et al.*, 1993, *J Immunol* 151(12): 6840-6852; Thomas and Lipsky, 1994, *J Immunol* 153: 4016-4028; O'Doherty *et al.*, 1993, *supra*). Alternatively, following 15 incubation of peripheral blood non-T cells or unpurified PBMC, the mature peripheral blood dendritic cells are characterised by low density and so can be purified on density gradients, including metrizamide and Nycodenz (Freudenthal and Steinman, 1990, *Proc Natl Acad Sci U S A* 87: 7698-7702; Vremec and Shortman, 1997, *J Immunol* 159: 565-573), or by specific monoclonal antibodies, such as but not limited to the CMRF-44 mAb (Fearnley *et al.*, 1999, *Blood* 93, 728-736; Vuckovic *et al.*, 1998, *Exp Hematol* 26: 1255-20 1264). Plasmacytoid dendritic cells can be purified directly from peripheral blood on the basis of cell surface markers, and then incubated in the presence of IL-3 (Grouard *et al.*, 1997, *supra*; Rissoan *et al.*, 1999, *supra*). Alternatively, plasmacytoid DC can be derived from density gradients or CMRF-44 selection of incubated peripheral blood cells as above.

25 In general, for dendritic cells generated from any precursor, when incubated in the presence of activation factors such as monocyte-derived cytokines, lipopolysaccharide and DNA containing CpG repeats, cytokines such as TNF- $\alpha$ , IL-6, IFN- $\alpha$ , IL-1 $\beta$ , necrotic cells, readherence, whole bacteria, membrane components, RNA or polyIC, immature dendritic cells will become activated (Clark, 2002, *J Leukoc Biol* 71: 388-400; Hacker *et al.*, 2002, *Immunology* 105: 245-251; Kaisho and Akira, 2002, *Biochim Biophys Acta* 1589: 1-13; 30 Koski *et al.*, 2001, *Crit Rev Immunol* 21: 179-189).

Other methods for isolation, expansion and/or maturation of dendritic cells are described for example by Takamizawa *et al.* (1997, *J Immunol*, 158(5): 2134-2142), Thomas and Lipsky (1994, *J Immunol*, 153(9): 4016-4028), O'Doherty *et al.* (1994,

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*Immunology*, 82(3): 487-93), Fearnley *et al.* (1997, *Blood*, 89(10): 3708-3716), Weissman *et al.* (1995, *Proc Natl Acad Sci U S A*, 92(3): 826-830), Freudenthal and Steinman (1990, *Proc Natl Acad Sci U S A*, 87(19): 7698-7702), Romani *et al.* (1996, *J Immunol Methods*, 196(2): 137-151), Reddy *et al.* (1997, *Blood*, 90(9): 3640-3646), Thurnher *et al.* (1997, 5 *Exp Hematol*, 25(3): 232-237), Caux *et al.* (1996, *J Exp Med*, 184(2): 695-706; 1996, *Blood*, 87(6): 2376-85), Luft *et al.* (1998, *Exp Hematol*, 26(6): 489-500; 1998, *J Immunol*, 161(4): 1947-1953), Cella *et al.* (1999, *J Exp Med*, 189(5): 821-829; 1997, *Nature*, 388(644): 782-787; 1996, *J Exp Med*, 184(2): 747-572), Ahonen *et al.* (1999, *Cell Immunol*, 197(1): 62-72) and Piemonti *et al.* (1999, *J Immunol*, 162(11): 6473-6481).

10 In certain embodiments, the antigen-presenting cells or their precursors are in the form of a substantially purified population of cells. In other embodiments, the antigen-presenting cells or their precursors are in the form of a heterogenous pool of cells. Suitably, the substantially purified or heterogenous population used to contact an antigen is cultured or uncultured as defined herein. In certain advantageous embodiments employing 15 an uncultured population of antigen-presenting cells or their precursors, the population can be incubated for short time periods (e.g., as low as about 5, 10, 15, 20, 20, 40, 50, 60 min) and the contacted population can be infused directly into a recipient without further culturing of the cells. This further shortens the processing time to permit potentially the harvesting of autologous or syngeneic antigen-presenting cells, treatment of those cells 20 with antigen and infusion of the antigen-contacted cells into a patient in a single sitting or day.

### 3.2 Delivery of antigen to antigen-presenting cells

The delivery of exogenous antigen to antigen-presenting cells can be enhanced by methods known to practitioners in the art. For example, several different strategies have 25 been developed for delivery of exogenous antigen to the endogenous processing pathway of antigen-presenting cells, especially dendritic cells. These methods include insertion of antigen into pH-sensitive liposomes (Zhou and Huang, 1994, *Immunomethods*, 4:229-235), osmotic lysis of pinosomes after pinocytic uptake of soluble antigen (Moore *et al.*, 1988, *Cell*, 54:777-785), coupling of antigens to potent adjuvants (Aichele *et al.*, 1990, *J. Exp. 30 Med.*, 171: 1815-1820; Gao *et al.*, 1991, *J. Immunol.*, 147: 3268-3273; Schulz *et al.*, 1991, *Proc. Natl. Acad. Sci. USA*, 88: 991-993; Kuzu *et al.*, 1993, *Euro. J. Immunol.*, 23: 1397-1400; and Jondal *et al.*, 1996, *Immunity* 5: 295-302) and apoptotic cell delivery of antigen (Albert *et al.* 1998, *Nature* 392:86-89; Albert *et al.* 1998, *Nature Med.* 4:1321-1324; and in

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International Publications WO 99/42564 and WO 01/85207). Recombinant bacteria (e.g. *E. coli*) or transfected host mammalian cells may be pulsed onto dendritic cells (as particulate antigen, or apoptotic bodies respectively) for antigen delivery. Recombinant chimeric virus-like particles (VLPs) have also been used as vehicles for delivery of exogenous heterologous antigen to the MHC class I processing pathway of a dendritic cell line (Bachmann *et al.*, 1996, *Eur. J. Immunol.*, 26(11): 2595-2600). In some embodiments, solubilized antigen (e.g., in DMSO) is incubated with antigen-presenting cells.

Alternatively, or in addition, an antigen (e.g., a peptide antigen) may be linked to, or otherwise associated with, a cytolysin to enhance the transfer of the peptide into the cytosol of an antigen-presenting cell of the invention for delivery to the MHC class I pathway. Exemplary cytolysins include saponin compounds such as saponin-containing Immune Stimulating Complexes (ISCOMs) (see e.g., Cox and Coulter, 1997, *Vaccine* 15(3): 248-256 and U.S. Patent No. 6,352,697), phospholipases (see, e.g., Camilli *et al.*, 1991, *J. Exp. Med.* 173: 751-754), pore-forming toxins (e.g., an alpha-toxin), natural cytolysins of gram-positive bacteria, such as listeriolysin O (LLO, e.g., Mengaud *et al.*, 1988, *Infect. Immun.* 56: 766-772 and Portnoy *et al.*, 1992, *Infect. Immun.* 60: 2710-2717), streptolysin O (SLO, e.g., Palmer *et al.*, 1998, *Biochemistry* 37(8): 2378-2383) and perfringolysin O (PFO, e.g., Rossjohn *et al.*, *Cell* 89(5): 685-692). Where the antigen-presenting cell is phagosomal, acid activated cytolysins may be advantageously used. For example, listeriolysin exhibits greater pore-forming ability at mildly acidic pH (the pH conditions within the phagosome), thereby facilitating delivery of vacuole (including phagosome and endosome) contents to the cytoplasm (see, e.g., Portnoy *et al.*, *Infect. Immun.* 1992, 60: 2710-2717).

The amount of antigen to be placed in contact with antigen-presenting cells can be determined empirically by persons of skill in the art. The antigen-presenting cells should be exposed to the antigen for a period of time sufficient for those cells to present the peptides or processed forms thereof for the modulation of T cells. In some advantageous embodiments the antigen-presenting cells are incubated in the presence of antigen for less than about 48, 36, 24, 12, 8, 7, 6, 5, 4, 3 or 2 hours or even for less than about 60, 50, 40, 30, 20, 15, 10, 9, 8, 7, 6, 5, 4, 3 or 2 minutes). The time and dose of peptides necessary for the cells to optionally process and present the peptides or their processed forms may be determined using pulse-chase protocols in which exposure to peptides is followed by a washout period and exposure to a read-out system e.g., antigen reactive T cells. Once the

optimal time and dose necessary for cells to express the peptides or their processed forms on their surface is determined, a protocol may be used to prepare cells and peptides for inducing immunogenic responses. Those of skill in the art will recognise in this regard that the length of time necessary for an antigen-presenting cell to present an antigen on its surface may vary depending on the antigen or form of antigen employed, its dose, and the antigen-presenting cell employed, as well as the conditions under which antigen loading is undertaken. These parameters can be determined by the skilled artisan using routine procedures. Efficiency of priming of the antigen-presenting cells can be determined by assaying T cell cytotoxic activity *in vitro* or using antigen-presenting cells as targets of CTLs. Other methods known to practitioners in the art, which can detect the presence of antigen on the surface of antigen-presenting cells after exposure to one or more of the modified and unmodified antigens, are also contemplated by the presented invention.

Usually, about 0.1 to 20  $\mu$ g/mL of antigen (e.g., peptide antigen) to about 1-10 million antigen-presenting cells is suitable for producing primed antigen-specific antigen-presenting cells. Typically antigen-presenting cells are incubated with antigen for about 1 to 6 hr at 37° C, although it is also possible to expose antigen-presenting cells to antigen for the duration of incubation with one or more growth factors. As discussed above, the present inventors have shown that successful presentation of antigen (e.g., peptide antigen) or their processed forms can be achieved using much shorter periods of incubation (e.g., about 5, 10, 15, 20, 30, 40, 50 minutes) using antigen at a concentration of about 10-20  $\mu$ g/mL.

#### 4. *Lymphocyte embodiments*

The antigen-presenting cells of the invention may be obtained or prepared to contain and/or express one or more antigens by any number of means, such that the antigen(s) or processed form(s) thereof, is (are) presented by those cells for potential modulation of other immune cells, including T lymphocytes and B lymphocytes, and particularly for producing T lymphocytes and B lymphocytes that are primed to respond to a specified antigen or group of antigens. In some embodiments, the subject antigen-presenting cells are useful for producing primed T lymphocytes to an antigen or group of antigens. The efficiency of inducing lymphocytes, especially T lymphocytes, to exhibit an immune response to a specified antigen can be determined by any suitable method including, but not limited to, assaying T lymphocyte cytolytic activity *in vitro* using for

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example antigen-specific antigen-presenting cells as targets of antigen-specific cytolytic T lymphocytes (CTL); assaying antigen-specific T lymphocyte proliferation (see, e.g., Vollenweider and Groseurth, 1992, *J. Immunol. Meth.* 149: 133-135), measuring B cell response to the antigen using, for example, ELISPOT assays, and ELISA assays; interrogating cytokine profiles; or measuring delayed-type hypersensitivity (DTH) responses by test of skin reactivity to a specified antigen (see, e.g., Chang *et al.* (1993, *Cancer Res.* 53: 1043-1050). Other methods known to practitioners in the art, which can detect the presence of antigen on the surface of antigen-presenting cells after exposure to the antigen, are also contemplated by the present invention.

Accordingly, the present invention also provides antigen-specific B or T lymphocytes, especially T lymphocytes, which respond in an antigen-specific fashion to representation of the antigen. In some embodiments, antigen-specific T lymphocytes are produced by contacting an antigen-presenting cell as defined above with a population of T lymphocytes, which may be obtained from any suitable source such as spleen or tonsil/lymph nodes but is preferably obtained from peripheral blood. The T lymphocytes can be used as crude preparations or as partially purified or substantially purified preparations, which are suitably obtained using standard techniques as, for example, described in "Immunochemical Techniques, Part G: Separation and Characterization of Lymphoid Cells" (*Meth. in Enzymol.* 108, Edited by Di Sabato *et al.*, 1984, Academic Press). This includes rosetting with sheep red blood cells, passage across columns of nylon wool or plastic adherence to deplete adherent cells, immunomagnetic or flow cytometric selection using appropriate monoclonal antibodies is known in the art.

The preparation of T lymphocytes is contacted with the antigen-presenting cells of the invention for an adequate period of time for priming the T lymphocytes to the antigen or antigens presented by those antigen-presenting cells. This period will preferably be at least about 1 day, and up to about 5 days.

In some embodiments, a population of antigen-presenting cells is cultured in the presence of a heterogeneous population of T lymphocytes, which is suitably obtained from peripheral blood, together with a set of peptides of the invention corresponding to an antigen to which an immune response is required. These cells are cultured for a period of time and under conditions sufficient for the peptides, or their processed forms, to be presented by the antigen-presenting cells; and the antigen-presenting cells to prime a subpopulation of the T lymphocytes to respond to the antigen.

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### 5. Cell based therapy or prophylaxis

The antigen-presenting cells described in Section 3 and the lymphocytes described in Section 4 can be administered to a patient, either by themselves or in combination, for modulating an immune response, especially for modulating an immune response to one or more cognate antigens. These cell based compositions are useful, therefore, for treating or preventing a disease or condition as noted above. The cells of the invention can be introduced into a patient by any means (e.g., injection), which produces the desired immune response to an antigen or group of antigens. The cells may be derived from the patient (*i.e.*, autologous cells) or from an individual or individuals who are MHC matched or mismatched (*i.e.*, allogeneic) with the patient. Typically, autologous cells are injected back into the patient from whom the source cells were obtained. The injection site may be subcutaneous, intraperitoneal, intramuscular, intradermal, intravenous or intralymphoid. The cells may be administered to a patient already suffering from a disease or condition or who is predisposed to a disease or condition in sufficient number to treat or prevent or alleviate the symptoms of the disease or condition. The number of cells injected into the patient in need of the treatment or prophylaxis may vary depending on *inter alia*, the antigen or antigens and size of the individual. This number may range for example between about  $10^3$  and  $10^{11}$ , and usually between about  $10^5$  and  $10^7$  cells (e.g., in the form of blood, PMBC or purified dendritic cells or T lymphocytes). Single or multiple administrations of the cells can be carried out with cell numbers and pattern being selected by the treating physician. The cells should be administered in a pharmaceutically acceptable carrier, which is non-toxic to the cells and the individual. Such carrier may be the growth medium in which the cells were grown, or any suitable buffering medium such as phosphate buffered saline. The cells may be administered alone or as an adjunct therapy in conjunction with other therapeutics known in the art for the treatment or prevention of unwanted immune responses for example but not limited to glucocorticoids, methotrexate, D-penicillamine, hydroxychloroquine, gold salts, sulfasalazine, TNF-alpha or interleukin-1 inhibitors, and/or other forms of specific immunotherapy.

### 6. Compositions

The overlapping sets of peptides described in Sections 2 and the antigen-primed antigen-presenting cells described in Section 3 or the lymphocytes described in Section 4 (therapeutic/prophylactic agents) can be used singly or together as active ingredients for the treatment or prophylaxis of various conditions associated with the presence of one or

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more target polypeptide antigens. These therapeutic/prophylactic agents can be administered to a patient either by themselves, or in compositions where they are mixed with a suitable pharmaceutically acceptable carrier and/or diluent, or an adjuvant.

The invention also encompasses a method for stimulating a patient's immune system, and preferably for eliciting a humoral and/or cellular immune response to a polypeptide of interest, by administering to the patient a therapeutic agent or composition as described above. Such stimulation may be utilised for the treatment and/or prophylaxis of a disease or condition including, but not restricted to, a pathogenic infection (e.g., viral, bacterial, fungal, protozoan) or a cancer. Accordingly, the invention contemplates a method for treatment and/or prophylaxis of a disease or condition, comprising administering to a patient in need of such treatment a therapeutically/prophylactically effective amount of a therapeutic agent or composition as broadly described above.

Depending on the specific conditions being treated, therapeutic/prophylactic agents may be formulated and administered systemically or locally. Techniques for formulation and administration may be found in "Remington's Pharmaceutical Sciences," Mack Publishing Co., Easton, Pa., latest edition. Suitable routes may, for example, include oral, rectal, transmucosal, or intestinal administration; parenteral delivery, including intramuscular, subcutaneous, intramedullary injections, as well as intrathecal, direct intraventricular, intravenous, intraperitoneal, intranasal, or intraocular injections. For injection, which constitutes one desirable embodiment of the present invention, the therapeutic agents of the invention may be formulated in aqueous solutions, preferably in physiologically compatible buffers such as Hanks' solution, Ringer's solution, or physiological saline buffer. For transmucosal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are generally known in the art. Intra-muscular and subcutaneous injection is appropriate, for example, for administration of immunogenic compositions, vaccines and DNA vaccines. In certain embodiments of the present invention, the immunogenic compositions are administered intravenously.

The therapeutic/prophylactic agents can be formulated readily using pharmaceutically acceptable carriers well known in the art into dosages suitable for oral administration. Such carriers enable the compounds of the invention to be formulated in dosage forms such as tablets, pills, capsules, liquids, gels, syrups, slurries, suspensions and the like, for oral ingestion by a patient to be treated. These carriers may be selected from

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sugars, starches, cellulose and its derivatives, malt, gelatine, talc, calcium sulphate, vegetable oils, synthetic oils, polyols, alginic acid, phosphate buffered solutions, emulsifiers, isotonic saline, and pyrogen-free water.

Pharmaceutical compositions suitable for use in the present invention include  
5 compositions wherein the active ingredients are contained in an effective amount to achieve its intended purpose. The dose of agent administered to a patient should be sufficient to effect a beneficial response in the patient over time such as a reduction in the symptoms associated with the condition. The quantity of the therapeutic/prophylactic agent(s) to be administered may depend on the subject to be treated inclusive of the age,  
10 sex, weight and general health condition thereof. In this regard, precise amounts of the therapeutic/prophylactic agent(s) for administration will depend on the judgement of the practitioner. In determining the effective amount of the agent to be administered in the treatment or prophylaxis of the condition, the physician may evaluate tissue levels of a target antigen, and progression of the disease or condition. In any event, those of skill in  
15 the art may readily determine suitable dosages of the therapeutic agents of the invention.

Pharmaceutical formulations for parenteral administration include aqueous solutions of the active compounds in water-soluble form. Additionally, suspensions of the active compounds may be prepared as appropriate oily injection suspensions. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acid esters, such as ethyl oleate or triglycerides, or liposomes. Aqueous injection suspensions may contain substances which increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, or dextran. Optionally, the suspension may also contain suitable stabilisers or agents which increase the solubility of the compounds to allow for the preparation of highly concentrated solutions.

25 Pharmaceutical preparations for oral use can be obtained by combining the active compounds with solid excipient, optionally grinding a resulting mixture, and processing the mixture of granules, after adding suitable auxiliaries, if desired, to obtain tablets or dragee cores. Suitable excipients are, in particular, fillers such as sugars, including lactose, sucrose, mannitol, or sorbitol; cellulose preparations such as, for example, maize starch, wheat starch, rice starch, potato starch, gelatin, gum tragacanth, methyl cellulose, hydroxypropylmethyl-cellulose, sodium carboxymethylcellulose, and/or polyvinylpyrrolidone (PVP). If desired, disintegrating agents may be added, such as the cross-linked polyvinyl pyrrolidone, agar, or alginic acid or a salt thereof such as sodium

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alginate. Such compositions may be prepared by any of the methods of pharmacy but all methods include the step of bringing into association one or more therapeutic agents as described above with the carrier which constitutes one or more necessary ingredients. In general, the pharmaceutical compositions of the present invention may be manufactured in  
5 a manner that is itself known, e.g., by means of conventional mixing, dissolving, granulating, dragee-making, levigating, emulsifying, encapsulating, entrapping or lyophilising processes.

Dragee cores are provided with suitable coatings. For this purpose, concentrated sugar solutions may be used, which may optionally contain gum arabic, talc, polyvinyl  
10 pyrrolidone, carbopol gel, polyethylene glycol, and/or titanium dioxide, lacquer solutions, and suitable organic solvents or solvent mixtures. Dyestuffs or pigments may be added to the tablets or dragee coatings for identification or to characterise different combinations of active compound doses.

Pharmaceutical which can be used orally include push-fit capsules made of  
15 gelatin, as well as soft, sealed capsules made of gelatin and a plasticiser, such as glycerol or sorbitol. The push-fit capsules can contain the active ingredients in admixture with filler such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilisers. In soft capsules, the active compounds may be dissolved or suspended in suitable liquids, such as fatty oils, liquid paraffin, or liquid  
20 polyethylene glycols. In addition, stabilisers may be added.

Dosage forms of the therapeutic agents of the invention may also include injecting or implanting controlled releasing devices designed specifically for this purpose or other forms of implants modified to act additionally in this fashion. Controlled release of an agent of the invention may be effected by coating the same, for example, with hydrophobic  
25 polymers including acrylic resins, waxes, higher aliphatic alcohols, polylactic and polyglycolic acids and certain cellulose derivatives such as hydroxypropylmethyl cellulose. In addition, controlled release may be effected by using other polymer matrices, liposomes and/or microspheres.

Therapeutic agents of the invention may be provided as salts with  
30 pharmaceutically compatible counterions. Pharmaceutically compatible salts may be formed with many acids, including but not limited to hydrochloric, sulphuric, acetic, lactic,

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tartaric, malic, succinic, etc. Salts tend to be more soluble in aqueous or other protonic solvents than are the corresponding free base forms.

For any compound used in the method of the invention, the effective dose can be estimated initially from cell culture assays. For example, a dose can be formulated in animal models to achieve a circulating concentration range that includes the IC<sub>50</sub> as determined in cell culture (e.g., the concentration of a test agent, which achieves a half-maximal reduction in target antigen). Such information can be used to more accurately determine useful doses in humans.

Toxicity and therapeutic efficacy of the compounds of the invention can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, e.g., for determining the LD<sub>50</sub> (the dose lethal to 50% of the population) and the ED<sub>50</sub> (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio LD<sub>50</sub>/ED<sub>50</sub>. Compounds that exhibit large therapeutic indices are preferred. The data obtained from these cell culture assays and animal studies can be used in formulating a range of dosage for use in humans. The dosage of such compounds lies preferably within a range of circulating concentrations that include the ED<sub>50</sub> with little or no toxicity. The dosage may vary within this range depending upon the dosage form employed and the route of administration utilised. The exact formulation, route of administration and dosage can be chosen by the individual physician in view of the patient's condition. (See for example Fingl *et al.*, 1975, in "The Pharmacological Basis of Therapeutics", Ch. 1 p1).

Dosage amount and interval may be adjusted individually to provide plasma levels of the active compound(s) which are sufficient to maintain target antigen-reducing effects or effects that ameliorate the disease or condition. Usual patient dosages for systemic administration range from 1-2000 mg/day, commonly from 1-250 mg/day, and typically from 10-150 mg/day. Stated in terms of patient body weight, usual dosages range from 0.02-25 mg/kg/day, commonly from 0.02-3 mg/kg/day, typically from 0.2-1.5 mg/kg/day. Stated in terms of patient body surface areas, usual dosages range from 0.5-1200 mg/m<sup>2</sup>/day, commonly from 0.5-150 mg/m<sup>2</sup>/day, typically from 5-100 mg/m<sup>2</sup>/day.

Alternately, one may administer the agent in a local rather than systemic manner, for example, via injection of the compound directly into a tissue, often in a depot or sustained release formulation. Furthermore, one may administer the agent in a targeted

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drug delivery system, for example, in a liposome coated with tissue-specific antibody. The liposomes will be targeted to and taken up selectively by the tissue.

From the foregoing, it will be appreciated that the agents of the invention may be used as therapeutic or prophylactic immunomodulating compositions or vaccines.

5 Accordingly, the invention extends to the production of immunomodulating compositions containing as active compounds one or more of the therapeutic/prophylactic agents of the invention. Any suitable procedure is contemplated for producing such vaccines. Exemplary procedures include, for example, those described in NEW GENERATION VACCINES (1997, Levine *et al.*, Marcel Dekker, Inc. New York, Basel Hong Kong).

10 Immunomodulating compositions according to the present invention can contain a physiologically acceptable diluent or excipient such as water, phosphate buffered saline and saline. They may also include an adjuvant as is well known in the art. Suitable adjuvants include, but are not limited to: surface active substances such as hexadecylamine, octadecylamine, octadecyl amino acid esters, lysolecithin, 15 dimethyldioctadecylammonium bromide, N, N-dicoctadecyl-N', N'bis(2-hydroxyethyl-propanediamine), methoxyhexadecylglycerol, and pluronic polyols; polyamines such as pyran, dextran sulfate, poly IC carbopol; peptides such as muramyl dipeptide and derivatives, dimethylglycine, tuftsin; oil emulsions; and mineral gels such as aluminum phosphate, aluminum hydroxide or alum; lymphokines, QuilA and immune stimulating 20 complexes (ISCOMS).

The antigen-primed antigen-presenting cells of the invention and antigen-specific T lymphocytes generated with these antigen-presenting cells, as described *supra*, can be used as active compounds in immunomodulating compositions for prophylactic or therapeutic applications. In some embodiments, the antigen-primed antigen-presenting 25 cells of the invention are useful for generating large numbers of CD8<sup>+</sup> or CD4+ CTL, for adoptive transfer to immunosuppressed individuals who are unable to mount normal immune responses. For example, antigen-specific CD8<sup>+</sup> CTL can be adoptively transferred for therapeutic purposes in individuals afflicted with HIV infection (Koup *et al.*, 1991, *J. Exp. Med.*, 174: 1593-1600; Carmichael *et al.*, 1993, *J. Exp. Med.*, 177: 249-256; and 30 Johnson *et al.*, 1992, *J. Exp. Med.*, 175: 961-971), malaria (Hill *et al.*, 1992, *Nature*, 360: 434-439) and malignant tumours such as melanoma (Van der Brogen *et al.*, 1991, *Science*, 254: 1643-1647; and Young and Steinman, 1990, *J. Exp. Med.*, 171: 1315-1332).

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In other embodiments, the immunomodulating composition of the invention is suitable for treatment or prophylaxis of a cancer. Cancers which could be suitably treated in accordance with the practices of this invention include cancers associated with a viral infection such as cervical cancer (e.g., papillomavirus infection) and Burkitt's lymphoma  
5 (e.g., Epstein Barr virus infection). Other virus associated cancers include, but are not restricted to, HTLV1 associated leukemia, Non Hodgkins lymphoma (EBV), anal cancer, skin cancer (HPV), hepatocellular carcinoma (HBV) and Kaposi's sarcoma (HHV8). Alternatively, the cancer may be a non-virally associated cancer such as but not limited to melanoma, lung cancer, breast cancer, prostate cancer, colon cancer, pancreatic cancer,  
10 stomach cancer, bladder cancer, kidney cancer, post transplant lymphoproliferative disease (PTLD), Hodgkin's Lymphoma and the like.

In still other embodiments, the immunomodulating composition is suitable for treatment or prophylaxis of a viral, bacterial or protozoan infection. Viral infections contemplated by the present invention include, but are not restricted to, infections caused  
15 by HIV, Hepatitis, Influenza, Japanese encephalitis virus, Epstein-Barr virus and respiratory syncytial virus. Bacterial infections include, but are not restricted to, those caused by *Neisseria* species, *Meningococcal* species, *Haemophilus* species *Salmonella* species, *Streptococcal* species, *Legionella* species and *Mycobacterium* species. Protozoan infections encompassed by the invention include, but are not restricted to, those caused by  
20 *Plasmodium* species (e.g., malaria), *Schistosoma* species (e.g., schistosomiasis), *Leishmania* species, *Trypanosoma* species, *Toxoplasma* species and *Giardia* species.

#### **7. Methods for assessing immunomodulation**

The effectiveness of the immunisation may be assessed using any suitable technique. An individual's capacity to respond to foreign or disease-specific antigens (e.g.,  
25 viral antigens and cancer antigens) may be determined by assessing whether those cells primed to attack such antigens are increased in number, activity, and ability to detect and destroy those antigens. Strength of immune response is measured by standard tests including: direct measurement of peripheral blood lymphocytes by means known to the art; natural killer cell cytotoxicity assays (see, e.g., Provinciali M. *et al* (1992, *J. Immunol. Meth.* 155: 19-24), cell proliferation assays (see, e.g., Vollenweider, I. and Groseurth, P. J.  
30 (1992, *J. Immunol. Meth.* 149: 133-135), immunoassays of immune cells and subsets (see, e.g., Loeffler, D. A., *et al.* (1992, *Cytom.* 13: 169-174); Rivoltini, L., *et al.* (1992, *Can. Immunol. Immunother.* 34: 241-251); or skin tests for cell-mediated immunity (see, e.g.,

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Chang, A. E. et al (1993, *Cancer Res.* 53: 1043-1050). Alternatively, the efficacy of the immunisation may be monitored using one or more techniques including, but not limited to, HLA class I tetramer staining - of both fresh and stimulated PBMCs (see for example Allen *et al.*, *supra*), proliferation assays (Allen *et al.*, *supra*), ELISPOT assays and

5 intracellular cytokine staining (Allen *et al.*, *supra*), ELISA Assays - for linear B cell responses; and Western blots of cell sample expressing the synthetic polynucleotides. Particularly relevant will be the cytokine profile of T cells activated by antigen, and more particularly the production and secretion of IFN  $\gamma$ , IL-2, IL4, IL5, IL-10, TGF $\beta$  and TNF  $\alpha$ .

10 The cytotoxic activity of T lymphocytes, and in particular the ability of cytotoxic T lymphocytes to be induced by antigen-presenting cells, may be assessed by any suitable technique known to those of skill in the art. For example, a sample comprising T lymphocytes to be assayed for cytotoxic activity is obtained and the T lymphocytes are then exposed to antigen-primed antigen-presenting cells, which have been caused to present antigen. After an appropriate period of time, which may be determined by assessing the cytotoxic activity of a control population of T lymphocytes which are known to be capable of being induced to become cytotoxic cells, the T lymphocytes to be assessed are tested for cytotoxic activity in a standard cytotoxic assay.

15 The method of assessing CTL activity is particularly useful for evaluating an individual's capacity to generate a cytotoxic response against cells expressing tumour or viral antigens. Accordingly, this method is useful for evaluating an individual's ability to mount an immune response to a cancer or virus. For example, CTL lysis assays may be employed using stimulated splenocytes or peripheral blood mononuclear cells (PBMC) on peptide coated or recombinant virus infected cells using  $^{51}\text{Cr}$  labelled target cells. Such 20 assays can be performed using for example primate, mouse or human cells (Allen *et al.*, 2000, *J. Immunol.* 164(9): 4968-4978 also Woodberry *et al.*, *infra*). In addition, cytotoxic T lymphocyte activity can be measured in outbred primates using the *in vivo* detection 25 method described in Figure 5.

30 In order that the invention may be readily understood and put into practical effect, particular preferred embodiments will now be described by way of the following non-limiting experimental example.

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## EXAMPLE

### MATERIALS AND METHODS

#### *Animals*

Male juvenile, colony-bred pigtailed macaques (*Macaca nemestrina*, aged 2-4 years) were studied. All animals were housed under PC3 biosafety conditions by trained animal technicians at the CSIRO Australian Animal Health Laboratory, Geelong. Prior to all procedures, animals were anaesthetised with ketamine (10 mg/kg, intramuscularly). Health and weight were routinely monitored. All conditions and protocols were approved by the CSIRO animal health and the University of Melbourne animal ethics committees.

10      *Pre-immunisations*

To evaluate whether the OPAL method could boost T cell responses in animals with pre-primed responses. T cell responses were induced in macaques by administering 2 DNA vaccines expressing HIV or SIV structural genes followed by a FPV boost vaccine expressing similar HIV or SIV genes as previously described (16). DNA vaccines in saline were administered twice intramuscularly (0.5 mL to each anterior quadracep) at a dose of 1mg/dose. FPV boosts were delivered intramuscularly a dose of  $5 \times 10^7$  pfu.

15      *Isolation of plasma and peripheral blood mononuclear cells (PBMC) from whole blood*

Blood was collected in 9 mL Na<sup>+</sup> Heparin and 3 mL EDTA vacutainers from the femoral vein of each animal on study weeks prior to and after vaccination and SHIV challenge. Plasma samples were removed following centrifugation (800×g, room temperature, RT, 8 min; Beckman Coulter) and stored in 3×1.5-mL tubes at -70° C. Plasma collected in EDTA-anticoagulated blood was used for RNA extraction. Media (RPMI-1640 supplemented with penicillin, streptomycin and glutamine; Invitrogen) equal to the volume of plasma collected was added to the blood and mixed prior to PBMC isolation on Ficoll-Paque, used according to the manufacturer's instructions (Amersham Pharmacia). PBMC were washed twice (500×g, 10° C, 6min) and resuspended in 1 mL media for counting (Beckman Coulter Counter®) in preparation of immunological assays.

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### *Overlapping peptides*

15-mer peptides (>80% purity) overlapping by 11 amino acids spanning the entire gag (125 peptides), pol (260 peptides) and nef (21 peptides) of SIV<sub>mac239</sub> and env (211 peptides) protein of SHIV<sub>SF162P3</sub> (NIH AIDS Research and Reference Reagent depository) (Figure 1-4) were pooled for each protein by solubilising each 1mg peptide aliquot in 10-40 µL of DMSO to final concentrations: SIV<sub>mac239</sub> gag (670 µg/mL or 730 µg/mL); pol (304 µg/mL), and; nef (4.762 mg/mL), and; SHIV<sub>SF162P3</sub> env (330 µg/mL), stored at -70° C until use. 18mer peptides overlapping by 11 amino acids spanning the entire HCV open reading frames (NIH AIDS Research and Reference Reagent depository) were pooled into 2 pools (HCV1 and HCV2) encompassing the structural and regulatory genes of HCV. Non-overlapping 17mer peptides spanning known sites of HIV-1 drug resistance mutations were specifically designed and purchased from Mimotopes Australia (Figure 25).

### *SIV antigens for in vitro analyses*

Whole inactivated SIV (WI SIV) and its control (supernatant from Hut78-CLE cell-line used to culture the WI SIV) (AIDS Vaccine Program, National Cancer Institute, MD) were stored at -70° C until use.

### *In vivo cytotoxic T lymphocyte killing*

At weeks 10, 15 and 20 following the initial vaccination, PBMC from the macaques were isolated from 40-50 mL blood, as described above. 25 mL sterile injectable saline was infused into the animals immediately after blood sampling to prevent hypovolemia. PBMC were resuspended in PBS and divided into 3 or 4 equal volumes, 0.5 mL. Cells were pulsed with SIVgag, pol, nef or SHIVenv peptide pools (10 µg/mL) or DMSO (volume of equal to the volume of SIVgag), in PBS for 90 min at 37° C, or on ice, with regular mixing. To subsequently track each peptide-pulsed cell population by flow cytometry, each peptide/DMSO-pulsed population was then labelled with a concentration of CFSE or SNARF (Molecular Probes). 5 mM CFSE stock in DMSO at-20° C was thawed and diluted in PBS. Neat SNARF stock was dissolved in 83 µL DMSO to make 1mM and diluted in PBS. Table 1 shows the final concentrations of each dye. Cells were mixed thoroughly and stained for 10 min in a 37° C waterbath, followed by one wash in RF5 then PBS (500×g, 10°C, 6min). All peptide/DMSO-pulsed cells for each animal were pooled in 1.5 mL saline for re-infusion into the femoral vein. 3 mL blood was sampled from the opposite femoral vein at 5 min, and at 4 and 16hr following infusion. Red blood

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cells were lysed with 10 mL FACS Lysing Solution (BD Biosciences), incubated for 10min at room temp. Cells were pelleted and washed twice with PBS (800×g, RT, 7min), and fixed with 1-2 mL 2% paraformaldehyde (Figure 5).

To determine whether cell populations were being selectively killed, 10<sup>6</sup> events gated live lymphocytes were collected by flow cytometry (FACSort Calibre, BD). CFSE and SNARF fluorescence were detected by FL1 and FL2 channels, respectively. For analysis, killing was expressed as the percentage of target versus control peptide-pulsed cell clearance. In the event of acquiring unequal labelled populations by flow cytometry at 5 minutes post-OPAL infusion, the degree of killing was subsequently scaled with respect to the initial population ratios obtained at 5 minutes. PBMC were also analysed prior to, and following, OPAL-infusion by IFN $\gamma$  ELISpot and ICS to detect whether T cell immune responses were enhanced.

#### *SHIV challenge of macaques*

To assess the efficacy to the vaccines, each macaque was inoculated intrarectally with SHIV<sub>mn229</sub> ( $5 \times 10^4$  TCID<sub>50</sub>/mL on CD8-depleted *M. nemestrina* PBMC) in 0.5 mL doses over 2 days (total 10<sup>5</sup> TCID<sub>50</sub>/mL) 18 weeks after the initial immunisation, as previously described (32).

#### *Quantification of viral SHIV RNA by reverse-transcriptase real-time PCR*

*RNA extraction:* To detect SHIV RNA in macaques following SHIV challenge, total RNA was initially extracted from stored plasma samples from anti-coagulated blood collected in EDTA with QIAamp® Viral RNA commercial kit (Qiagen) as previously described (32). Briefly, plasma samples were centrifuged (500×g, RT, 10min) to remove cells (preventing DNA contamination). 140 μL plasma RNA coupled to Carrier RNA in Buffer AVL and 96-100% ethanol was centrifuged and bound to a filter membrane. 60 μL RNA was eluted with Buffer AW1 and AW2 through a spin column. All reagents except ethanol supplied by kit.

*Reverse-transcriptase PCR:* 10 μL RNA was then reverse transcribed into cDNA, in duplicate, with the reaction mixture (20 μL): 2.9 μL RNase/DNAse-free water (Promega); 3 μL 10× TaqMan buffer A (Applied Biosystems); 6 μL MgCl<sub>2</sub> (25nM) (Applied Biosystems); 1.5 μL Random Hexamers (diluted 1/2; Applied Biosystems); 6μl dNTPs (2.5nM; Promega); 1.5 μL; Promega); 0.5 μL Rnasin (40 U/mL; Promega); 0.1 μL

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MMLV-RT superscript (200U/mL; Invitrogen), for one thermal cycle: 25° C (15min) → 42° C (40min) → 75° C (5min) (GeneAmp PCR System 9700, Applied Biosystems). A third test per sample was set up to assess the presence of SHIV DNA contamination, using the same reaction mix excluding MMLV-RT superscript. SIV RNA standards (33) were 5 serially diluted and reverse-transcribed in duplicate (limit of detection, 1500 copies/mL).

Real-time PCR: cDNA was amplified with reaction mixture (20 µl): 141µl RNase/DNAse-free water (Promega); 2µL 10× PCR buffer II (Applied Biosystems); 1 µL MgCl<sub>2</sub> (Applied Biosystems); 1 µL SL03 SIVgag (20pmol/µL); 1µL SL04 SIVgag (20 pmol/µL); 0.3 µL SL07 molecular beacon 0.5µL Tag Gold (Applied Biosystems) as 10 previously described (33). Reaction temperature was initially raised and held at 95 °C for 10 min to activate Tag Gold enzyme, followed by 45 thermal cycles: 95° C (15 sec) → 55° C (30 sec) → 72 °C (30 sec). Real-time analysis was performed on amplicon detection at 55° C (30 sec) stages by Sequence Detector software v1.6.3 (Applied Biosystems).

CD4+ T cell counts

15 To assess the depletion of CD4+ T cells following SHIV challenge, 200 µL whole blood was incubated with 5 µL PE-conjugated anti-human CD3, 5 µL FITC-conjugated anti-human CD4, 5 µL PerCP-conjugated anti-human CD8 (clone SP34; L200, and; Leu-2a, respectively; BD Pharmingen) monoclonal antibodies for 20 min in dark, RT. Red blood cells were lysed with 2 mL FACS Lysing Solution (BD Biosciences) and fixed as 20 described in method 2.8. 50,000 total events were collected by 3-colour FACScan Calibre® and CD4+ and CD8+ T cell counts expressed as the percentage of gated lymphocytes.

Analysis of stimulation or induction of SHIV, HCV and peptides derived from resistant HIV-1 strains by the whole blood OPAL technique

25 In a separate experiment to assess (a) whether peptide-pulsed whole blood (as compared to PBMC which had be used previously) could be effectively used as an immune stimulant and (b) whether the OPAL technique could stimulate *de novo*, un-primed, immune responses, selected SHIV-infected macaques were infused with either whole blood pulsed at 5 µg/mL for 1hr with either a series of overlapping 15mer SHIV peptides 30 (3 pools) or a series of overlapping 18mer HCV peptides (2 pools) and a series of non-

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overlapping 17mer peptides encompassing known mutations induced by HIV-1 drugs as illustrated in Figures 22-24.

## RESULTS

### In vivo cytotoxic T-lymphocyte killing

5        The standard measure of virus-specific CTL effector is measured *via* the release of a radioisotope  $^{51}\text{Cr}$  from target cells, an assay that is tedious and poorly sensitive. By pulsing dye-labelled autologous macaque PBMC with large pools of SIV and SHIV overlapping peptides (OPAL) and infusing the cells back into the same animal, the inventors were able to kinetically show SHIV-specific killing in blood sampled at various  
10 time-points following the infusion of OPAL by flow cytometry.

Two weeks after full immunisation (week 10), three of four immunised animals displayed moderate to large (11.4-76%) killing of gag-pulsed PBMC by 16 hours post-OPAL infusion, whereas control-immunised monkeys displayed <7% gag-specific killing.  
15        One immunised animal, monkey H20, demonstrated vigorous gag-specific killing (27.3%) as early as 4 hours post-infusion (Figure 6). These data were consistent with T cell responses induced by the vaccines as analysed by IFN $\gamma$  ELISpot and ICS (data not shown), indicating the usefulness of OPAL to measure effective CTL effector responses primed by the DNA and FPV vaccines.

20        Shortly (2 weeks) after SHIV intrarectal challenge all four immunised animals exhibited large degrees of gag-specific killing (65-98.3%) 16 hours post-OPAL infusion, and two of four (monkeys H20 and H21) further demonstrated >99% pol-specific killing (Figure 7). In comparison with control-immunised animals, monkey E20 displayed <6% killing of both gag- and pol-pulsed PBMC whereas monkey E22 showed >90% and 31.9% of gag- and pol-pulsed PBMC, respectively. Interestingly, the animals that displayed moderate to high degrees of pol-specific killing (monkeys H20, H21 and E22) were also the only animals that had previously received 2 doses of infused pol-pulsed PBMC (weeks 10 and 15), whereas monkeys B00, H8 and E20 received pol-pulsed PBMC only once prior. This observation suggests that the infusion of OPAL may have: (a) boosted pol-specific T cell responses primed by the vaccines that were weakly or not detected by IFN $\gamma$  ELISpot and ICS (data not shown), and; (b) induced pol-specific immunity in naïve animals evident post-SHIV challenge.  
25  
30

Analysis of the immunogenicity induced by infusing peptide-pulsed autologous cells.

It seemed plausible that if *in vivo* CTL killing could be efficiently measured by OPAL infusion, this method may be able to either prime a new or boost an existing immune response. IFN $\gamma$  ELISpot and ICS assays were therefore performed prior to- and one week following each OPAL infusion assay to analyse whether there would be an increase in T cell immunogenicity previously primed by the vaccines or by the OPAL infusion method itself (Figure 8).

Following the first OPAL infusion performed at week 10, a 3- to 16-fold increase in IFN $\gamma$ -secreting cells to SIV gag peptide pool was detected in monkeys H20 and H21, measuring up to 430 spot-forming cells (Figure 9). Monkey H8 measured a 54% increase to 215 spot-forming cells, whereas no increase was measured in control-immunised animals. Analysis of monkeys B00 (post-OPAL infusion) and E20 (pre-OPAL infusion) for all antigens analysed were excluded due to developmental problems of the assay. Of the four animals that received pol-pulsing at week 10, monkeys H20, H21 and E22, displayed increased pol responses by up to 140 spot-forming cells post-OPAL infusion, whereas no significant ELISpot responses were detected in monkey E20. No nef-specific T cell was in all animals apparent before or after OPAL-infusion. These results suggest a boosting effect in T cell immunogenicity following gag- and pol-peptide pulsing in the animals previously primed for SIVgag/pol responses, and furthermore indicate priming for SIVpol in a naïve animal (monkey E22).

At week 15, 8 weeks following full immunisation, a second OPAL infusion assay was performed in the six animals. ELISpot analyses revealed increased responses to gag peptide pool by up to 500 spot-forming cells from approximately 50 or less spot-forming cells prior to OPAL infusion in the four animals pre-immunised with DNA and FPV vaccines. In control-immunised animals, no gag-specific T cells were measured before or after the assay (Figure 10). In comparison, a slight increase in pol-specific responses (up to 40 spot-forming cells) from baseline was measured in only a few animals. Large increased responses to WI SIV were measured in all pre-immunised animals (up to 450 spot-forming cells), whereas control-immunised animals displayed modest or no increases (up to 50 spot-forming cells). All responses to SIV nef and SHIV env were minimal or undetected in all animals prior to and after OPAL infusion.

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Following SHIV intrarectal challenge, all animals except monkey E20 displayed increased gag responses measuring between 50-600 spot-forming cells. Similar responses were observed for WI SIV but to levels up to 200 spot-forming cells, whereas pol responses above 50 spot-forming cells were only evident in monkey H20.

5 The immunogenicity of OPAL infusion was further verified by comparison to animals that received the same immunisation regimen but did not receive OPAL infusion (Figure 11). No rise in SIV gag, pol or WI SIV-specific T cells were detected in groups 1 (control-immunised) and 2 (2xDNA/FPV-immunised) from weeks 9 to 11 and 15 to 18. Responses from weeks 20 to 21 increased slightly the groups, attributable to responses  
10 enhanced by SHIV challenge at week 18.

15 The experiments performed on macaques infused with peptide pulsed whole blood also demonstrated a boost in CD4+ and CD8+ T cell responses to both (a) several parts of SHIV in recipients of SHIV-peptide pulsed blood (Figure 22), (b) 2 pools of HCV peptides spanning the entire HCV genome in recipients of HCV-peptide pulsed blood (Figure 23), and (c) a pool of peptides spanning known HIV-1 drug resistant mutations in recipients of autologous blood pulsed with HIV-1 resistant peptides (Figure 24).

#### Outcome of SHIV<sub>mm229</sub> intrarectal challenge

The highly pathogenic SHIV<sub>mm229</sub> challenge stock was inoculated intrarectally into all macaques 10 weeks after full immunisation at a dose of 10<sup>5</sup> TCID<sub>50</sub>. Plasma SHIV  
20 RNA and CD4+ T cell counts were followed in all control-and 2xDNA/FPV-immunised animals (Figure 12).

Control-immunised monkeys E20 and E22 exhibited peak viral loads of 7.8±0.7 log<sub>10</sub> copies/mL at 2 weeks following challenge. The peak viral load of monkey E20 may have occurred between week 1 and 2, however, set-point levels of both monkeys  
25 (measured 5 to 11 weeks post challenge) remained high at 5.9±0.3 log<sub>10</sub> copies/mL. Conversely at week 2, CD4+ T cell counts dropped dramatically to 1.6±1.1% of total lymphocytes, and set-point levels were steady at 0.3±0.2%. Monkeys that received the same immunisations but no OPAL infusions (group 1) performed only marginally worse than monkeys E20 and E22 in terms of peak and set-point viral loads (8.2±0.1 log<sub>10</sub>  
30 copies/mL and 6.2±0.3 log<sub>10</sub> copies/mL), as well as CD4+ counts (set-point 0.5±0.3%).

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- Based on the enhanced pol-specific killing that may have been attributed to 2 separate OPAL infusions, the SHIV viral loads and CD4+ T cell counts of monkeys H20 and H21 were compared to monkeys B00 and H8 that received only 1 dose of pol-OPAL infusions. Peak viral load of monkeys H20 and H21 (receiving 2 pol-OPAL infusions) was 5 at least 10-fold lower than monkeys B00 and H8 ( $5.9 \pm 1.3$  vs.  $7.1 \pm 0.4$  log<sub>10</sub> copies/mL,  $P=0.08$ ), and set-point viral load showed a trend towards being lower ( $4.1 \pm 0.9$  vs.  $5.4 \pm 0.7$  log<sub>10</sub> copies/mL,  $P=0.08$ , student's *t* test). Incidentally, set-point CD4+ T cell count for monkeys H20 and H21 was significantly greater than monkeys B00 and H8 ( $18.9 \pm 6.1\%$  vs. 10  $8.4\%$ ,  $P=0.02$ ). Although statistically insignificant in comparison with group 2 animals who received the same immunisations but no OPAL infusions ( $P=0.12$ ), monkeys H20 and H21 that received multiple pol-OPAL infusions displayed a trend towards the retention of CD4+ T cells although viral loads were relatively similar, indicative of viral challenge protection. Set-point CD4+ T cell count and viral load of group 2 were  $13.0 \pm 3.7\%$  and  $4.8 \pm 0.2$  log<sub>10</sub> copies/mL, respectively.
- 15 In comparison to control-immunised monkeys E20 and E22, both set-point viral load and CD4+ T cell count of monkeys H20 and H21 were significantly different ( $P=0.01$ ,  $P=0.00$ ). The set-point viral load of monkeys B00 and H8, on the other hand, was not significantly lower than monkeys E20 and E22 ( $P=0.37$ ) despite significant set-point levels of CD4+ T cells ( $P=0.01$ ). Note that monkey H20 had completely cleared plasma 20 viral RNA from week 5 and onwards and retained CD4+ T cells at normal levels.

#### **DISCUSSION**

The vital role for HIV-1-specific CD4+ T-helper (Th) and CD8+ CTL responses in controlling HIV-1 replication is the focus of many current vaccine concepts. The infusion of autologous PBMC pulsed with large overlapping sets of SHIV 15mer peptides (OPAL) was surprisingly immunogenic in its ability to boost SHIV-specific immune responses as analysed by IFN $\gamma$  ELISpot and ICS assays. This finding forms the potential basis of a novel vaccine or immunotherapeutic strategy as described herein.

The evidence for this immunogenicity of peptide-pulsed fresh PBMC was five-fold: (a) Increases in SIV gag-specific IFN $\gamma$  ELISpot responses were observed one week 30 after each of the 3 SIV gag OPAL infusions (week 10, 15, and 20) in all vaccinated monkeys. In contrast, at week 10 and 15, SIVgag responses in equivalently immunised animals (group 2) not receiving the OPAL infusion significantly declined. (b) Increases in

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SIV pol-specific IFN $\gamma$  ELISpot responses were observed in immunised animals one week following the SIV pol infusion at week 10 and 20. Interestingly this was observed in only the two monkeys H20 and H21 that received multiple SIV pol OPAL infusions prior to SHIV challenge (weeks 10 and 15) and not in animals receiving SIV pol peptide pulsed cells at week 15. This is of particular interest since the pol-specific T cell responses to the DNA and FPV vaccines alone were modest or undetectable by ELISpot and ICS. (c) High levels of SIV pol-specific *in vivo* killing were also seen in the two monkeys that received 2 prior infusions of SIV pol OPAL infusions. (d) This immunogenicity data was further confirmed by high levels of SIV pol-specific IFN $\gamma$  intracellular cytokine responses in the 10 two immunised animals receiving the multiple SIV pol OPAL infusions. (e) There was a trend towards greater protection from SHIV challenge in animals receiving multiple OPAL infusions. Together, these results suggest that pulsing autologous PBMC *ex vivo* with pools of overlapping peptides is an effective method for boosting immune responses. In addition, data show that peptide pulsed whole blood can both stimulate T cell responses to several 15 parts of SHIV in recipients of SHIV-peptide pulsed blood, as well as induce *de novo* T cell responses to (a) 2 pools of HCV peptides spanning the entire HCV genome in recipients of HCV-peptide pulsed blood and (b) a pool of peptides spanning known HIV-1 drug resistant mutations in recipients of autologous blood pulsed with HIV-1 resistant peptides.

There is a body of data ascertaining the use of pulsing autologous or syngeneic 20 cells with defined peptide epitopes or whole antigen for the induction (or 'cross-priming') of immune responses (22, 23, 27, 34, 35). The use of specialised antigen presenting cells such as monocyte-derived dendritic cells pulsed with, for example, single tumour antigens or whole inactivated SIV has also been studied extensively as an immunotherapeutic tool 25 (36-39). However, to the inventors' knowledge this is the first report of utilising large peptide pools spanning an entire protein (125 SIV gag 15mers or 263 SIV pol 15mers) and the use of whole PBMC cultured for short periods *ex vivo*, as a method of boosting immune responses.

In one control-immunised animal, monkey E22, which received multiple infusions 30 of PMBC pulsed with SIV pol (and SIV gag), a modest induction of SIV gag and SIV pol-specific IFN $\gamma$  ELISpot responses was detected. This animal subsequently had high levels of SIV gag- and pol-specific killing analysed at week 20, presumably from the boosting effect of the SHIV challenge. The efficiency of priming an immune response by OPAL infusion therefore seems feasible. These data were confirmed when whole blood was

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pulsed with HCV or HIV-1 drug resistant peptides, which efficiently induced high levels of CD4+ and CD8+ T cell responses as assessed by ICS. These data also demonstrate the feasibility of using whole blood as an antigen-presenting cell (APC) source, which would be more practical than PBMC or other more complex APC preparations (such as monocyte-derived dendritic cells) in the field.

Further modifications to the OPAL technique, such as the enrichment for APC and/or dendritic cells (DC) (40), would potentially enhance the immunogenicity of OPAL infusion as a therapeutic vaccine since DC cultured from PBMC of HIV-infected patients (41, 42) and SIV-infected animals (40) can elicit potent T-cell responses. Alternatively, the prospect of using whole blood rather than PBMC fractions as a means of delivering OPAL will certainly benefit a clinical setting, particularly for HIV-infected persons. Furthermore, a smaller whole blood sample may not require as high a concentration of peptide since 1 µg/mL is effective *in vitro* for whole blood analysis by ICS. It is also conceivable that direct intravenous infection of pooled peptides would mimic the immunogenicity of the

OPAL effect. The use of consensus HIV-1 clade peptide sets of gag and pol offers the broad epitopic breadth desired of an effective therapeutic vaccine for humans. The immunogenicity of antigens that regulate viral replication, such as rev, tat, vpu, vif and vpr, which are poorly immunogenic by current vaccine approaches, should also be improved using this strategy. In addition, the general method of using blood or PBMC or other uncultured APC-containing fraction directly as an APC source immediately suggests the possibility of pulsing other sources of antigen (including but not limited to whole protein, DNA, live vector vaccines or cancer cell preparations) onto such APC populations prior to infusion. It is believed that such antigen-loaded cell APC populations could be more immunogenic (presumably by binding directly to abundant APCs) than administering

the antigen by other common methods such as intramuscularly (where few APCs exist).

The disclosure of every patent, patent application, and publication cited herein is hereby incorporated herein by reference in its entirety.

The citation of any reference herein should not be construed as an admission that such reference is available as "Prior Art" to the instant application.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications. The

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invention also includes all of the steps, features, compositions and compounds referred to or indicated in this specification, individually or collectively, and any and all combinations of any two or more of said steps or features.

DATED this Twenty-fifth Day of March, 2004

5

**THE UNIVERSITY OF MELBOURNE**

By their Patent Attorneys

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(41) IEEKKFGCAEVVPGFQALSECCTPYDINGKLNCGDQAAMQIIRDINNEAADDWLQHPPAPQQQLRSPSSDIAGTTSSVEDEQIQWNYRQOMPPIPVGMLYRRWIOGLKCURMNYNPTNILDVKQGPKEPFQSYVDRFTYKSLSRAEQTDAAVQNMUTOTLLQIANEDC  
IEEKKGCAEVVPGFQDFQ  
EVVPGFQALSEGCTP  
GFPQALSEGCTPYDIN  
LSEGCTPYDINGKLN  
CTPYDINGKLNCGD  
DINGKLNCGD  
MLNCVGDKHOAMQII  
VGDHQAAAMQIIRDIT  
QIIRDINNEAADDWL  
DINEEADDWLQHPPAP  
EEAADWLQHPPAPQGQ  
DWDLQHPPAPQGQ  
QHPPAPQGQOLREP  
PAPQGQOLREP  
GCQLRFSGSDIACT  
REPSGSDIAGTTSYY  
GSDIAGTTSYDEQI  
(61) 8SVDEQIQWNYRQOM  
EQIOWNYRQOMPIEV  
WNYRQOMPIPVGNIV  
QOMPPIPVGMLYRRW  
IPVGMLYRRWIOGL  
WYRRWIOGLQXCV  
RWIQGLQKCURMNY  
IGLQKCURMNYNPTNI  
KCURMNYNPTNILDVK  
TWILDVKQGPKEPFQ  
DVVKQGPKEPFQSYWD  
GPKEPFQSYVDRFYK  
PPQSYVDRFTYKSLSRA  
LRAEQTDAAVKREMT  
QTDAAVKREMTOTLL  
AVQNMUTOTLLQIANEDC  
(62) WMTOTLLQIANEDC

FIGURE 1

(81) TLLIQANPDKLIVLKGIGVNPTEKEMIATACGTVGSGQKARLMALAKRALAPVPIPAAQORGPRKPITXCMACGGKCHSAROCRAPRQGCKHCGIAOHWAKCDPDRAGFLGLPHICKKPRNFPMQVHOGLMPTAPPDPAVDLIAYNQOLGKQQRKORESREKPK

(82) QMANPDKLIVLKGIG  
PDKLIVLKGIGVNFT  
LWKGGLGVNPTEEM  
GLGVNPTEEMTAC  
NPTLEEMTACVGTG  
EEMLTACVGTGCG  
TACGTVGGPGQKARL  
GVGGPGQKARLMABA  
(90) RGQKARLMAEALKEA  
ARIMAEALKEALAPV  
AEALKEALAPVPIP  
KEALAPVPIPFAAQ  
AFVPIPAAQORGPRGP  
IPRAAACQORGPRKP  
ARQORGPRKPICKMN  
RGPRKPICKMNCSK  
XPIKCRICKECHSA  
CNCCKEGHSARQCR  
(100) QKCHSAROCRAPR

(101) HSAROCRAPRQGCK  
OCRAPRQGCKKCK  
PRQGCKKQGRDHEV  
GCNKCTORMDHVMAKC  
CGKADHDYMAKCPCDQ  
DHYMAKCPCDQAGFL  
AXCPDROAGFLGP  
DROAGFLGPAGFLGP  
GPAGFLGPAGFLGP  
(110) LGPAGFLGPAGFLGP  
GKKEPNFPMQVHQG  
RNFPMAQVHQGILMPT  
HQGILMPTAPPEDPAV  
MPTAPPEDPAVDTLK  
PPRDPAVDTLKHMQ  
PAVDLIXNQOLGKQ  
JLKRYNQJGTCQREK  
YDQLERKQREKQRES  
(120) GRCQREKQRESREKPK

(121) REKQRESREKPKYKEVTEDLIHLNSLFGGQ  
REKQRESREKPKYKEV  
RESEKPKYKEVTEDL  
EKPKYKEVTEDLIHLN  
KEVTEDLIHLNSLFG  
(125) EDLHLNSLFGGQ

FIGURE 1 contd

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## FIGURE 2

## FIGURE 2 contd

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(A1) DAYFSI PLOEDEFRQTAFTLPSVNUBEPGKRYIYKVLPQGMKCSPAIIFOYTRASHVLEPFRANPUVTLYQANDDILIASDRTDLERHDVVLQSKELANSIGESTPEERKQDPPFQNGYELNMPTRKTLQRIELPQRBTYTNDIQKLGVNLWAAQIYPGIKTKHL  
 (101) EHDRLSHDAVVLQSKELNS  
 EHDRVVQDQSKELNS  
 VYLQSKELNSIGSTSPEE  
 SKELNSIGSTSPEE  
 INSIGSTSPEE  
 GFSTPPEEKFOQDPPP  
 FEEKFQDQDPPPTQMG  
 FQKDPPPPQMGYELW  
 PPFDQWQMGYELWPTKWL  
 (110) KNGYBLWPTKWLQK  
 BLNPPTKWLQKIELP  
 LQKIELPQRETWTW  
 LQKIELPQRETWTW  
 RERETWTW  
 RETWTW  
 TWDTOKLGVNLWAAQIY  
 TQKLGVNLWAAQIYFGIK  
 NTAQIYPGIKTKHL  
 (120) QIYPGIKTKHLCKLJ

(A2) GRTKHULCRUJRGKMTLTEEVONTENAEAEYEENKILSQEQEGCYQEGCPLAETVIKSQDNQWSYKIHQEDKILKVGKRAMLKNTHTNGVRLLAHYIOMIGKEAIVWKGQVPKFHLPVKDMDWQEQHDTDXQVTTWIPENDPISSTPLVRLVENVXDPIEGEESTYTDG  
 (141) FAM1 KRTHTNGVRLL  
 KRTHTNGVRLLAHYI  
 TNGVRLLAHYI  
 RLLAHYIOMIGKEA1  
 HVIQKIGKEAIVTWG  
 KIGKEAIVWGSQVK  
 EAIVWGSQVKPHLP  
 IWSQVPKPHLP  
 VPKEFHLPVKDOWED  
 (150) HLTVEKDVKDWEQWKT  
 EKDVVEQWKTDXQV  
 HEQWKTDXQVTPVLP  
 WTDYRQVWVTPWEDP  
 WQTVWIPBWDPISTP  
 WDFSTPPAVRLVFN  
 STPPAVRLVFNLYKO  
 LVRLVFNLYDPIEG  
 VPLVVDPIEGESTY  
 (160) VDPIEGESTYTDG

(A3) GRTKHULCRUJRGKMTZ  
 KHLCRLJRGKMTZ  
 RUEGRKMTLVEUON  
 GOMTLEEVONTENAE  
 LTEEVONTENAEAFY  
 VONTENAEAYEENK  
 AYEENKILSQE0S  
 ENK1ILSQE0CCTY  
 ENK1ILSQE0CCTY  
 EMASAEYEENKILS  
 (130) ILSQE0BGCYYQEGK  
 EQECCYYQEGKPLEA  
 CYYQEGKPLEATVIK  
 EGKPLEATVIKSDN  
 LRATVIKSDNQWWSY  
 VLNQDQNQWSYKIHQ  
 QDNQWSYKIHQSDK1  
 HSXKTHQEDKILKVG  
 IHQEDKILKVGKFAK  
 DKILKVGKFAK1KT  
 (140) KVGKFAK1KTHTNG

(161) IEGBETTYTDGSCNKOKECKAGYITDKGKDVKVLEQTTINQAEELAFLMALTDGPKXANTIVDQSXYMGIITGCPTESESRLVQITEEMIKKESKEIYAWVPAHKGICGENOBIDHLVSOGIRQVLFLEKISPAQEHDICHTSYKSLVFKEGLPRIVARQIVDTCDKCH  
 (181) ESHLNUQIIBRMKK  
 VNQIIEENIKKSEIV  
 IEMIKKSEIVYAWV  
 IKKSEIVYAWVPAHKSGEG  
 EIVIAWVPAHKSGEG  
 AIVPAHKSGEGNEI  
 AHKGICGNOEIDHLV  
 IGGNQEIDHLVSOGI  
 QEIIDLHSOGIRQVL  
 (190) HLYVSOGIRQVLFLEX  
 OGIRQVLFLEXKIP  
 QVLFLFKIEPQQEEH  
 LEKIEPQQEHDICHH  
 SPAQEHDICHHNVK  
 REHDKHNSNKELV  
 KTHSNKELVFKFCGL  
 NYKELVFKFCGLPRIV  
 LIVFKELPRIVARQIVDT  
 FGFLPRIVARQIVDT  
 (200) RIVARQIVDTCDKCR

(170) EQTTTQAEELAFLM  
 NDAELRAFLMALT  
 ELEAFALALTDSGPK  
 LTDGPQXANIVDSD  
 GPXANIVDSDGPK  
 NIIVDSDQYMGILIG  
 DSQYMGILIGCPE  
 VNGLITGCPESESR  
 ITGCCPTESESRLVQ  
 (180) PTESESRLVQIIRZ

(201) RQIVDTCDKCHQGEAINGQANSDLGTQWDCTHLEGKIIIVAVRVASeFIRAEVIPOTGROTALEFLKLQGRMPITHLKTONGANFASQEVYAWHACIETEGVYNPOSQCVETAMTHLKNQIDIREQANSVETIVLMAVHCMQPKRGGIGDMTPAERLIMMI  
 (221) ITDNGAMFASQYTM  
 GANFASQYTMKVKH  
 ASQEVYTMKVKHAGIE  
 YKRVAKVAGIAGTFC  
 ANTAGI EHTFGVPM  
 GIEHTFGVPM  
 TFGVPTDOSQGVWE  
 PTPDOSQGVWEAMH  
 OSQGVVRAMTHLHN  
 (230) WYRMMTHLKNQIDR  
 MNTHLKNQIDRREQ  
 LKNOIDRREQANSV  
 TORLREQANSVETIV  
 REQANSVETIVLMAV  
 ASVETIVLMAVHCM  
 TIVLMAVHCMFPRR  
 MAVHCMFPRRGIGDMTP  
 CMAPFRGGIGDMTPAERL  
 KRGGIGDMTPAERL  
 (240) GIGDMTPAERLIMMI

(210) GKIIIVAVRVASeF  
 THLECKIIIVAVRVA  
 LGTMONDTHLHK  
 QNDCTTHLEGKIIIV  
 KGEAIIHQANSADLOT  
 IHQOANSADLOTMD  
 ANSDLGTMODCTHL  
 (220) GFIEAVIPQETGQ  
 HVASGFIEAVIPQ  
 AEVIPQETGQTAFLF  
 PQEIQQTALFLKL  
 GRQTAFLFLKLAGR  
 ALFLCLAGRWPITH  
 LKLAGRWPITHLTD  
 GRWPITHLTDGAN  
 (230) ITDNGAMFASQ

FIGURE 2 contd

(241) KTPAERLIMMITTEQIQQQRNISKPKXPNFRVYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
ERLIMMITTEQIQQQRNISKPKXPNISKPKXPNFRVYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
NMITTEQEIQQSKPKXPNISKPKXPNFRVYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
TEQIIQFQQSKPKXPNFRVYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
IQPQQQRNISKPKXPNFRVYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
QSRSKPKXPNFRVYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
SKFKNFRTYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
NFRVYREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
YREGRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
(250) GRDQLKPGCBLWKGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
LMXGPGLAMXGEGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
PGELIMKREGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
LMKGECAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
EGAVILKVGDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
ILKVGTDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
GTDIKVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
KVVPPRKAKMIIKDYGGKEVDSSESSHMDTGGEARVA  
RKKRIIKNYDGGE  
KIIKDYGGKEVDSSESSHMDTGGEARVA  
(260) DYGGGKEVDSSESSHMDTGGEARVA

FIGURE 2 contd

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(1) MCGAISMRSSRSPSCDLRQLLARGETYGRLLGEVEDCYSSPGGLDKLSSCSEQIKNYQGQVATTPWNPAPEREKAYRKQNMDDIDE  
ISMRRSRSPSGDLROR  
RSRPSGDURQRLRA  
SGDURQRLRARGET  
RQRLRARGETYGRLL  
LARGETYGRLLGEV  
GETYGRLLGEVEDGY  
GRALGEVEDGSQSOP  
GEVEDGTSQSOPGELD  
(10) DCTYSQSPGELDKLS  
QSPGCLURGLSSLSC  
GLIKOLLSLSZCZQK  
GLSSLACZCZQKYNOC  
LSCZCZQKYNOCQMMN  
GQKYNODGQMMATPWR  
NOGQMMATPWRXPAE  
YANTPWRNPAPEREK  
PHENPAPEREKAYR  
PAEREKAYRKQNMDDID  
(20) REKAYRKQNMDDID

FIGURE 3

(1) MRVKGIRKNGQHLMRGCTLLGMLMICSAYEKLWVTTYGVPAKKEATTIIFCSADAKAYDTEVHNWVATIACVPTDPNPOEVILENTENPMTA  
 (21) PDEIVLLENTEVPMH\*  
 G1RKNGQHLMRGCTL  
 NYQHLMRGCTLLGMIC  
 LMRGCTLLGMIC  
 GTLLGMICMSAYE  
 LQMLMICMSAYE  
 MICSAYEKLWVTTY  
 AVEKLWVTTYGVPA  
 LAVTVYGVPAWKA  
 (10) VYGGPAKKEATTI  
 VPANEKKEATTI  
 KEATTIIFCSADAKA  
 TTIFCSADAKAYDT  
 CASDAKYDTTEHNA  
 ARAYDTTEHNAWATH  
 DTEHNAWATHACV  
 HAWPAHACVPTD  
 ATHACVPTDNPQEII  
 CVPDENDPQEIVTEN  
 (20) DRNPQEIVLEN  
 T  
 TTSIGNKQKEYALFYLDVPTDNNTSYLNCTSVITQACPVSFPIPHCAPAGFAILKCRDKXPNQSGUPCINVSTVQCTHGRPPVSTQTLINGSLAEGTVIRSENFTDNVKTIIIVQKESVEINCRTPTNTKSIPIGPKAFAYATEDIGDIRQAHCN  
 (41) TSIGNKQKEYALFYLD  
 GNOVQKEYALFYALF  
 MQKEYALFYRLD\*  
 YALFYRLDNPVIDND  
 YRLDVPIDNDNTSY  
 VYPIDNDNTSYLN  
 DNDNTSYLNINCNTS  
 TSYMLINCNTSYLN  
 LINCNTSYLNINCNTS  
 ITQACPVSFPIPI  
 CPKVSFEPIPKVA  
 SFEPIPKVA  
 IPHYCAPAGFAIUK  
 YCAPAGFAIUKCNDK  
 AGFAIUKCNDKENG  
 NDKENGKUENGSGPC  
 ENSGCPVCINSTVOC  
 (50) GPCINSTVOC  
 TTSIGNKQKEYALFYLDVPTDNNTSYLNCTSVITQACPVSFPIPHCAPAGFAILKCRDKXPNQSGUPCINVSTVQCTHGRPPVSTQTLINGSLAEGTVIRSENFTDNVKTIIIVQKESVEINCRTPTNTKSIPIGPKAFAYATEDIGDIRQAHCN  
 (61) TSIGNKQKEYALFYLD  
 VQCTHGRPPVSTQI,  
 HGTRPPVSTQI  
 FVVSTQTLINGSLAE  
 TQTLINGSLAEGTV  
 INGBLAEGTVIRSE  
 LAEGTVIRSE  
 GVIRSE  
 RSENFTDNVKTIIIVQ  
 VTKTIIIVQKESVEIN  
 KESVEINCRTPTNT  
 EINCRTPTNTKSIPIG  
 ANTRKSIPIGPKAF  
 KSIPIGPKAFAYATEDIG  
 XAFYATCDIGOIRO  
 (60) ATGDIQDIGOIRO  
 TTSIGNKQKEYALFYLDVPTDNNTSYLNCTSVITQACPVSFPIPHCAPAGFAILKCRDKXPNQSGUPCINVSTVQCTHGRPPVSTQTLINGSLAEGTVIRSENFTDNVKTIIIVQKESVEINCRTPTNTKSIPIGPKAFAYATEDIGDIRQAHCN  
 (70) TSIGNKQKEYALFYLD  
 GNOVQKEYALFYALF  
 MQKEYALFYRLD\*  
 YALFYRLDNPVIDND  
 YRLDVPIDNDNTSY  
 VYPIDNDNTSYLN  
 DNDNTSYLNINCNTS  
 TSYMLINCNTSYLN  
 LINCNTSYLNINCNTS  
 ITQACPVSFPIPI  
 CPKVSFEPIPKVA  
 SFEPIPKVA  
 IPHYCAPAGFAIUK  
 YCAPAGFAIUKCNDK  
 AGFAIUKCNDKENG  
 NDKENGKUENGSGPC  
 ENSGCPVCINSTVOC  
 (80) GPCINSTVOC

FIGURE 4

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FIGURE 4 contd.

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FIGURE 4 contd.

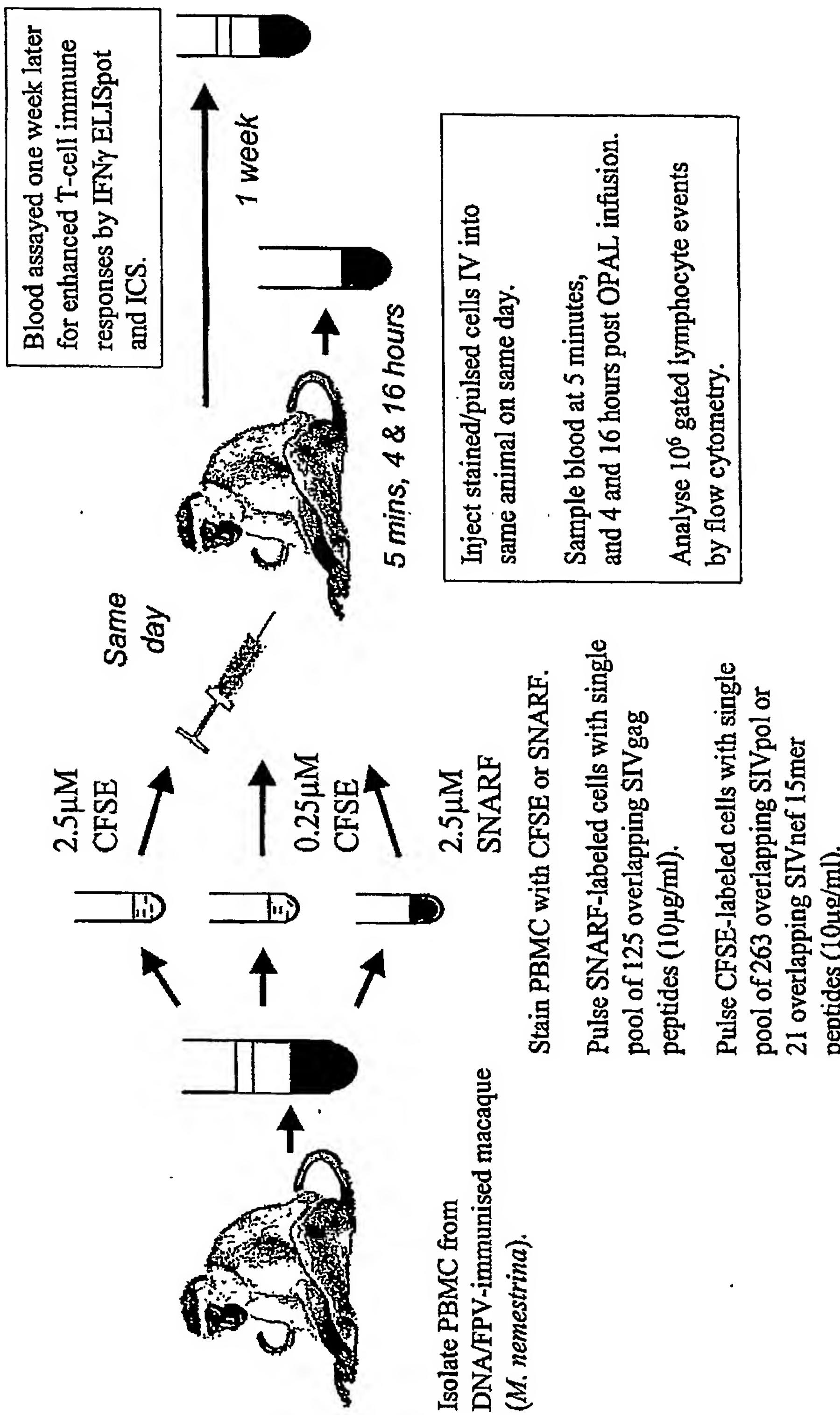
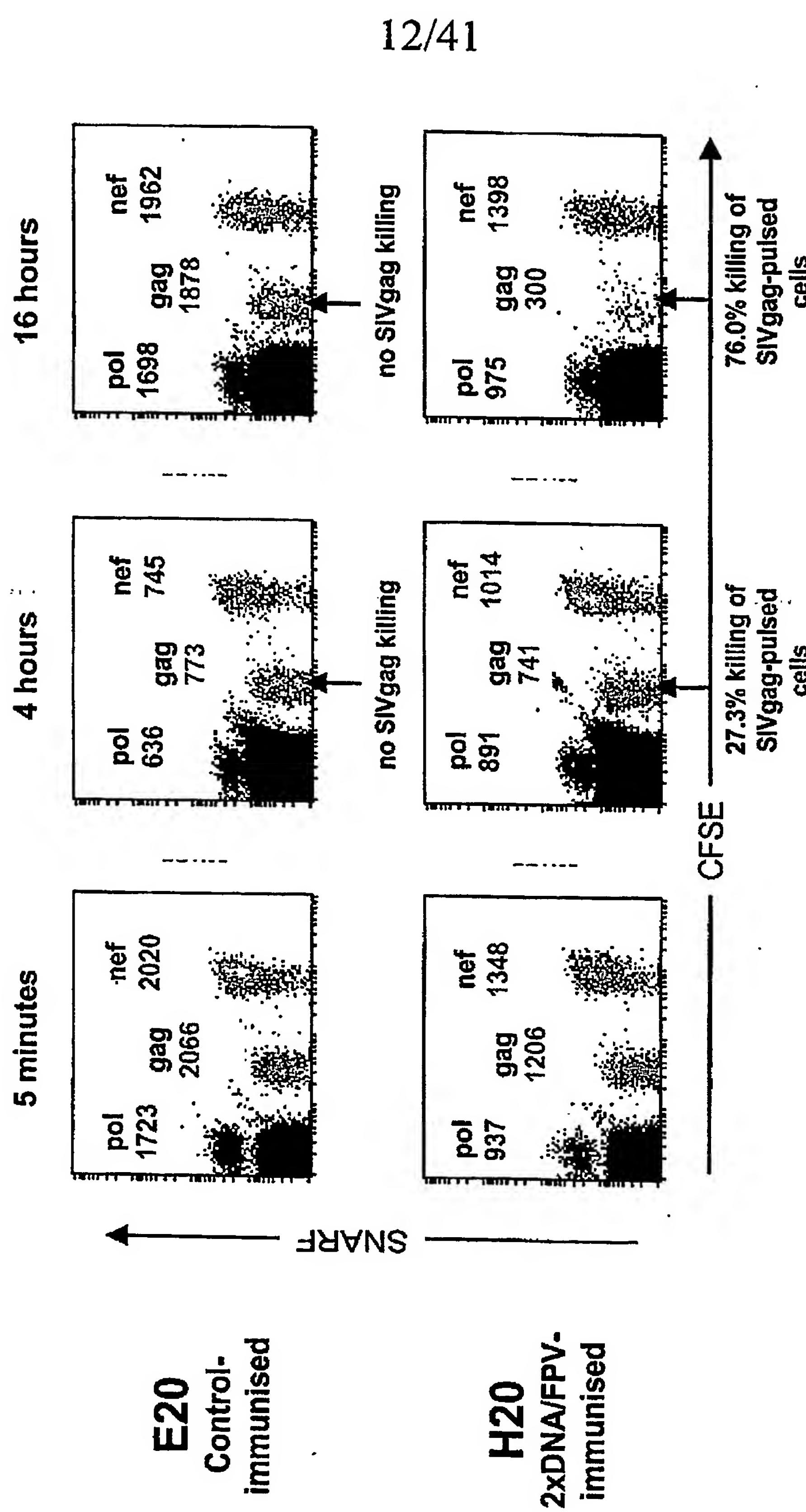


FIGURE 5

**FIGURE 6**



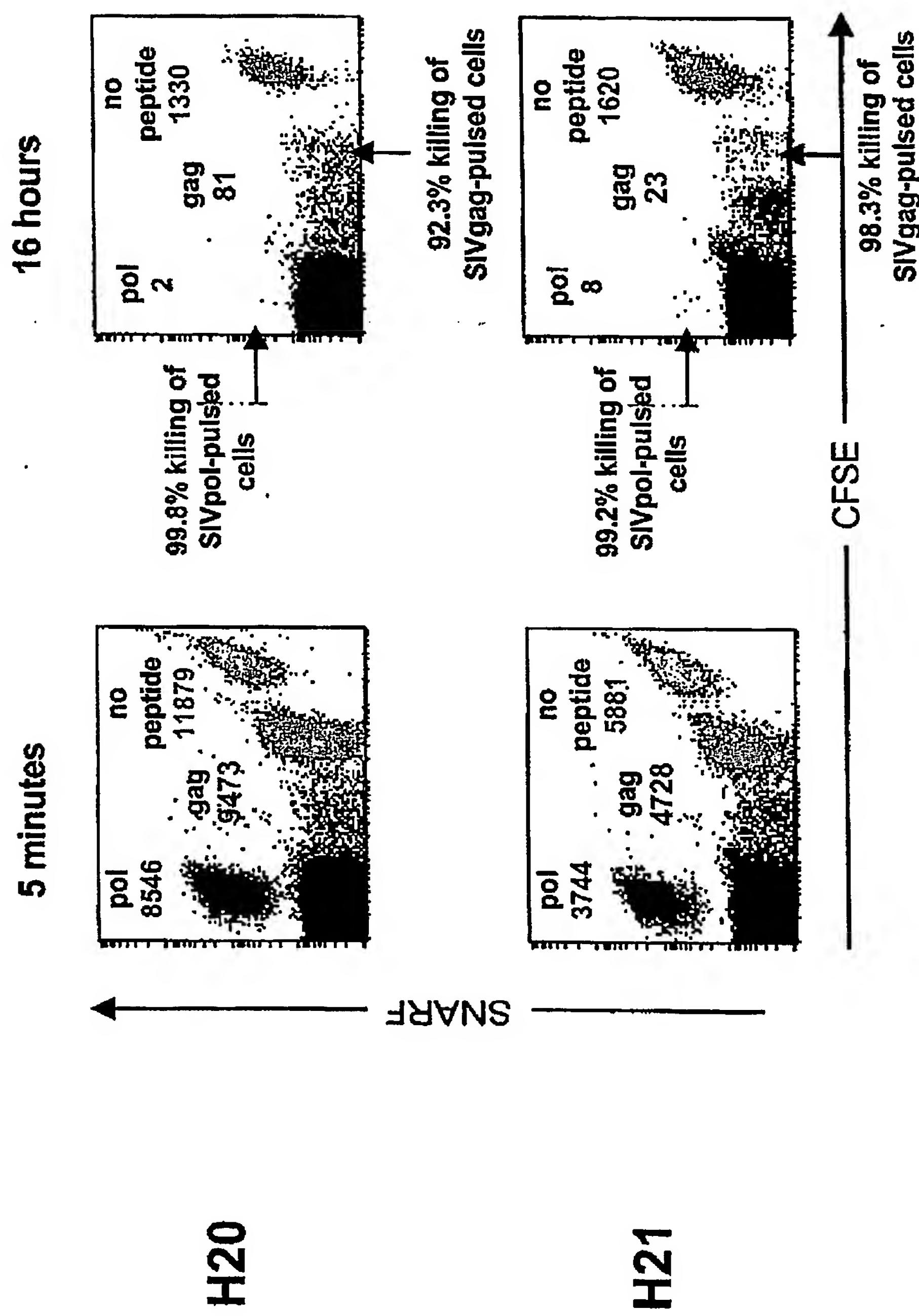
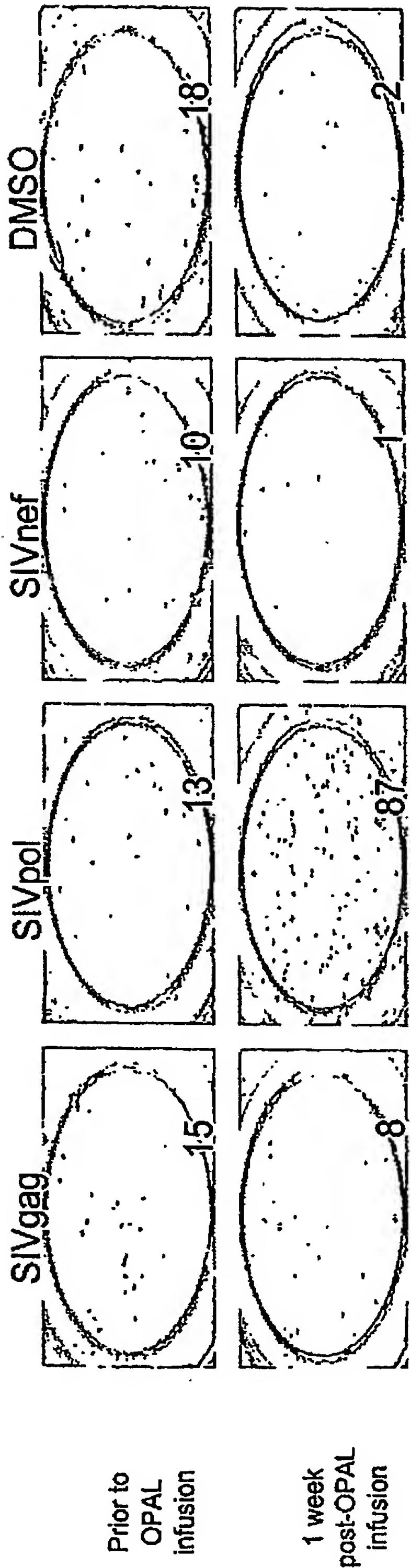
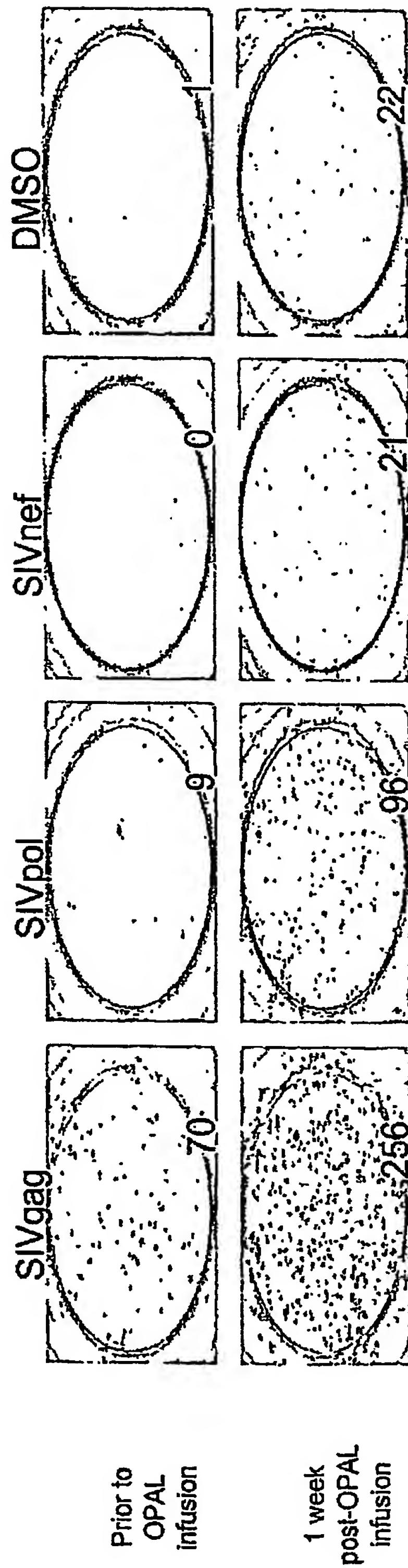


FIGURE 7

**E22 - control-immunised animal****H20 - 2xDNA/FPV-immunised animal****FIGURE 8**

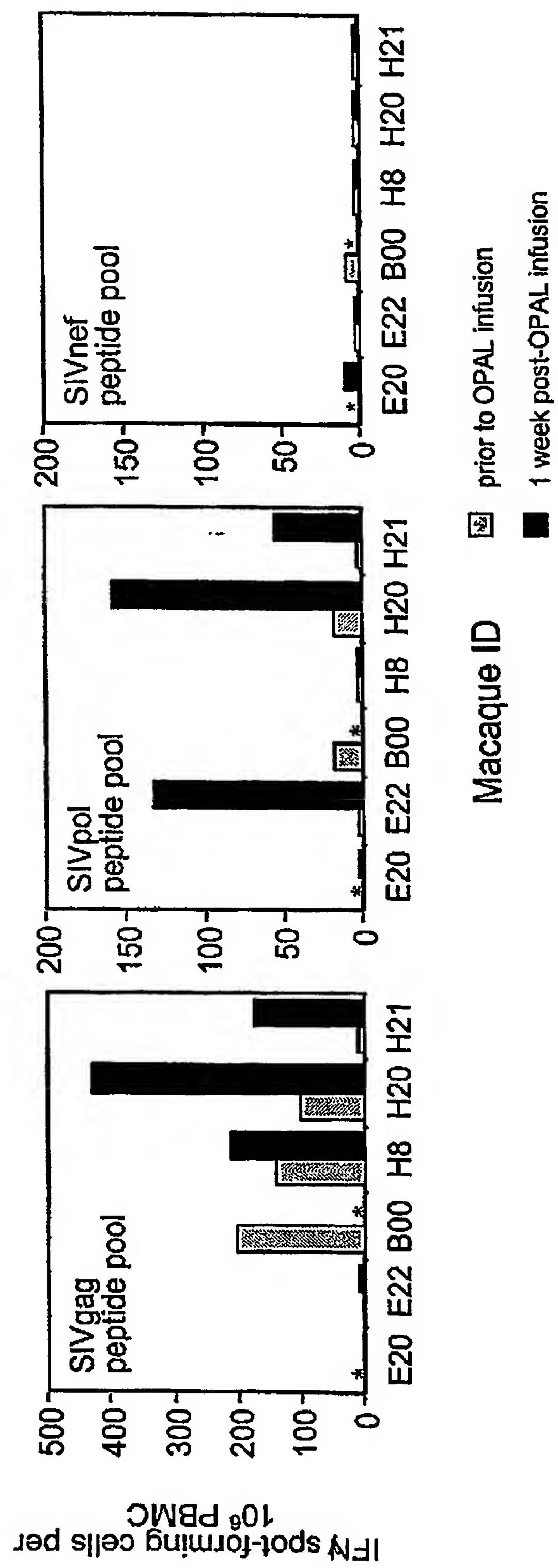


FIGURE 9

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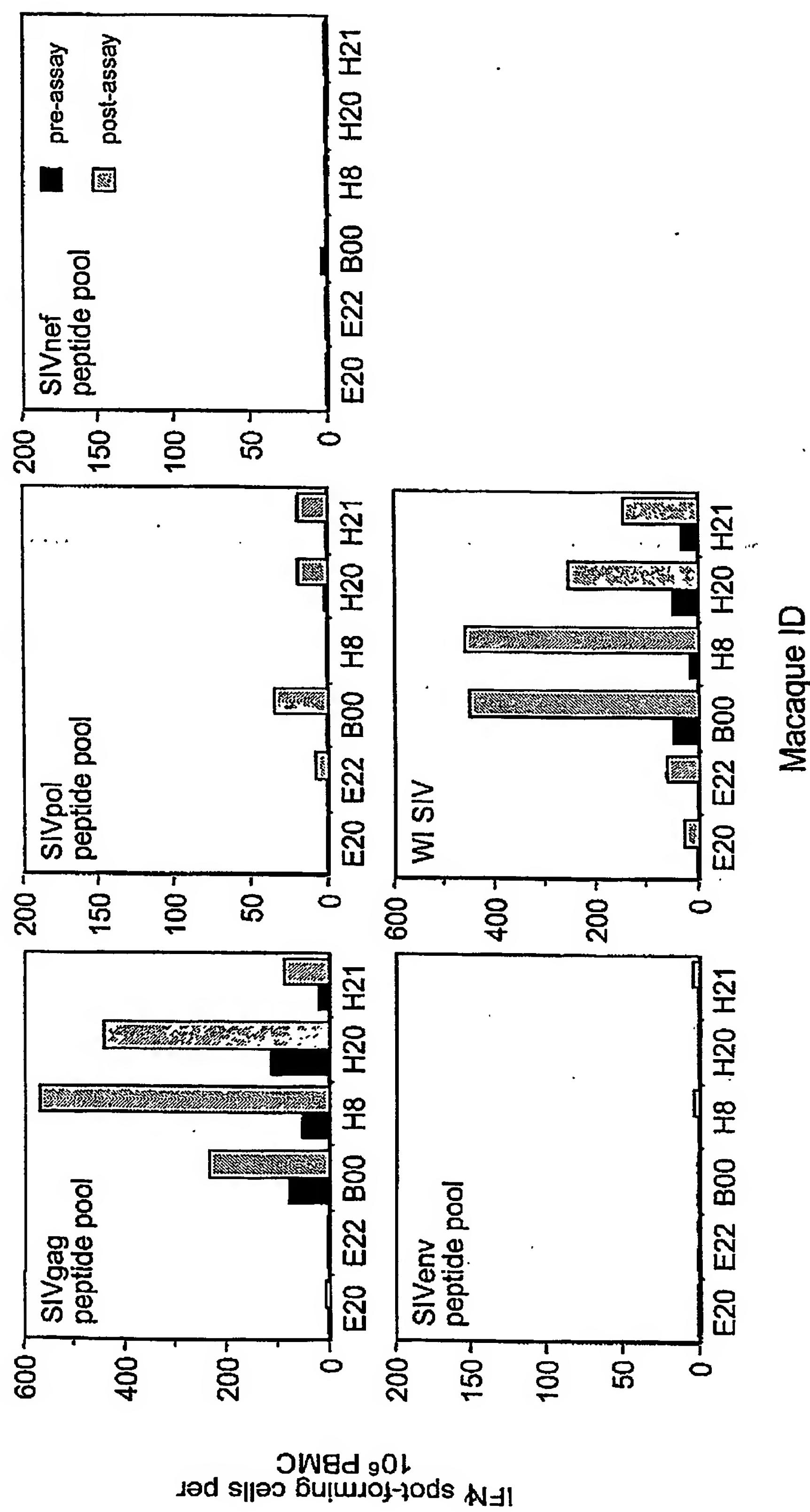
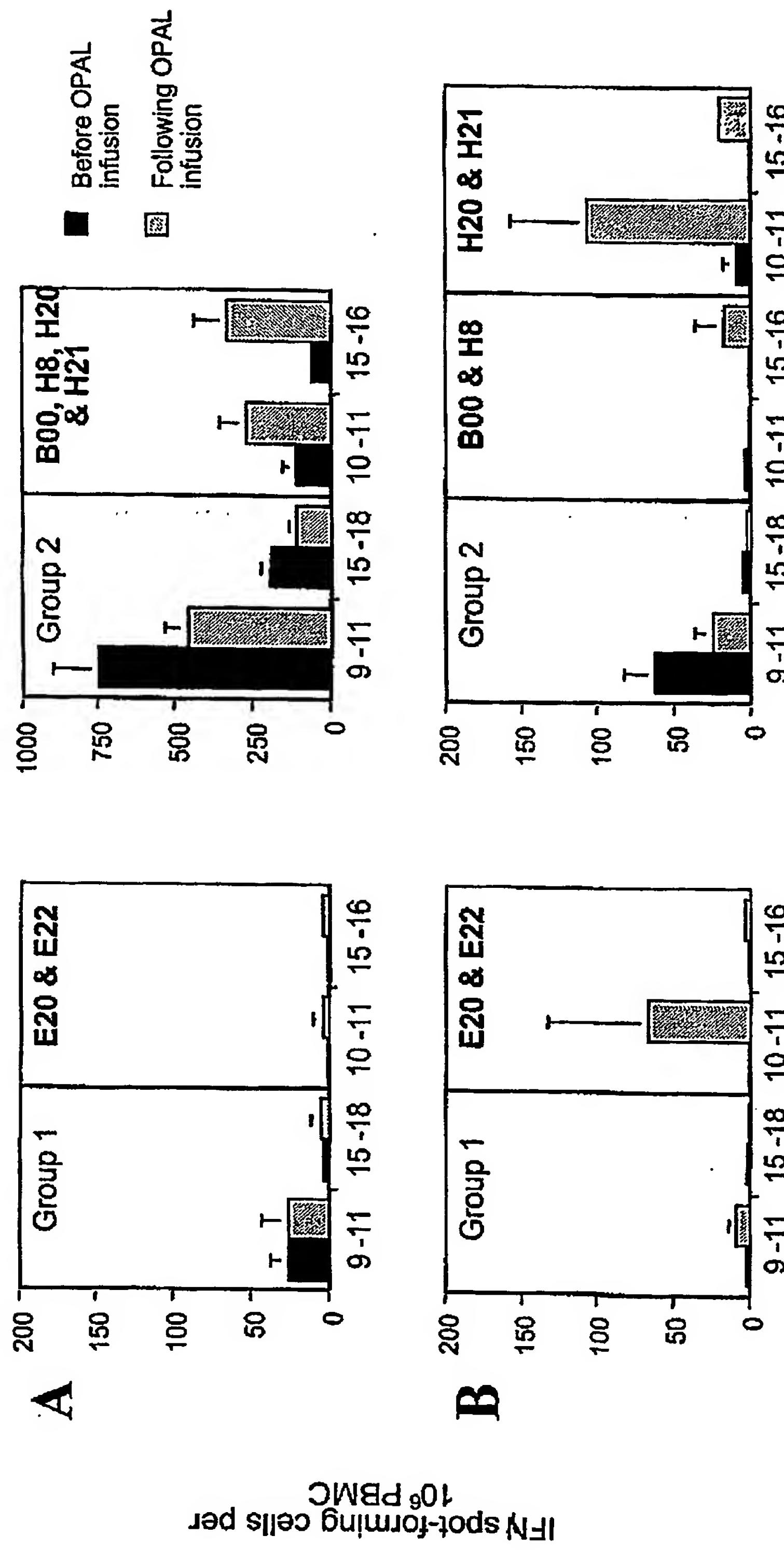


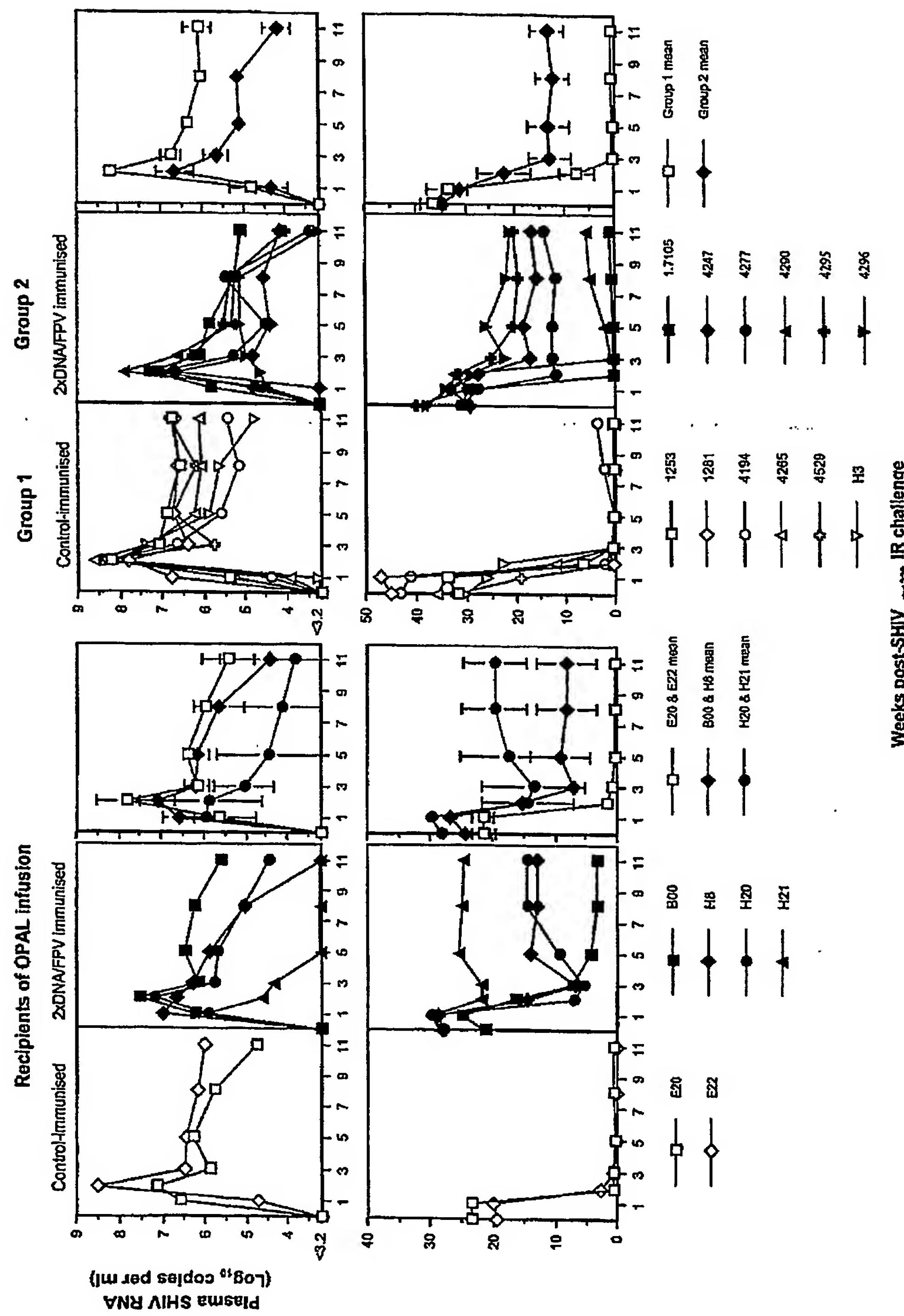
FIGURE 10

**Control-immunised  
animals**

**2xDNA/FPV-immunised  
animals**



**FIGURE 11**



# FIGURE 13

(1) MEARASVLSGELDRWIKIRLRPGSKKKYKLKHIVASRETERPAWNPGILETSEGCRQILQLQPSLOTGSBELESLXNTVATLYCVRORIEVKDTKEALEKIEEEQNKSKKAAQPAADTGNSQSOSQSONYPIVQNLQGQMVHQIISPERTLNANVKVYBEXAFSPEVIP

(21) NTVALEYCVRORIEVKDTK  
TLYCVHORIEVKDTK  
VHORIEVKDTKBALE  
IEVKDTKEALEKIEE  
DTKEALEKIEESENQK  
ALEKIEESENQSKCK  
TEEQNKSKKAAQQAADT  
KKKAQQQAADTONISS  
(30) QQAADTONISSQVSQ  
ADTGNSQSOSQVSYPI  
NSSQVSONYPIVQNL  
VSQNVIPITVQNLQGOMVHOR  
YPIVQNLQGOMVHOR  
ONLOGOMVHORISPR  
GOMVHORISPRTLNA  
HQAIISPERTLNATVYKV  
SPRTLNATVYKVVEBK  
LNATVYKVVEBKAFSPESP  
(40) VVVEEEKAFAFSPEVIP

(10) ASRELLERFANRGL  
ELERFANRGLLETSECR  
FGLLETSECRQILG  
ETSEGERQILGQIOP  
GCRQILGQIOPSLOT  
ILCQIOPSLQTGSE  
LQPSELQIOPSEELSIL  
LQTGSEELSILNTVY  
SPELRSILNTVATLY  
(20) RSLXNTVATLYCVHQ

(41) BEKAESPEVIMFSALSEGATPODINTMANTVGHHQMLKETINBEAENDRJHPVHAGPIAPGMRPREGSDIAGTSTLQEIGMTNNPIVCEYKRWILLGLNKIVRMETSILDIRECPKEPFRDYVDRFYTILRAEQASEVNTNFTLUVQNANPD  
ERKAESPEVIMFSALSEGATPODINTMANTVGHHQMLKETINBEAENDRJHPVHAGPIAPGMRPREGSDIAGTSTLQEIGMTNNPIVCEYKRWILLGLNKIVRMETSILDIRECPKEPFRDYVDRFYTILRAEQASEVNTNFTLUVQNANPD  
(61) TTSITLQEIGMTNN  
LQEIQGMNTNNPPPIP  
IGNATNNPPPIP  
TNNPPPIPQGELYKRW  
PIFGEIYKREWILG  
GEIYERWILGELTKI  
KRWILGELTKIVRM  
NIGLANKIVRMYSPTS  
NIKIVRMYSPTSILDI  
(70) PTSILDIRGKPEFSP  
PTSILDIRGKPEFRTVV  
LDIKGKPEFRTVV  
QGPKEPFPFDYDRFYT  
EPFRDYDRFYTILRAEQ  
DVTDRFYTILRAEQ  
RFYKTJRAEQASQEV  
TIRAFQASQEVWMM  
EQASQEVWMMTETL  
QEVWMMTETLUVQN  
(80) NMWTTLVQNAUPD

(15) AMOMQMLKETI  
LNTVGGHQMLKETI  
GHDQAMQMLKETI  
LNTVGGHQMLKETI  
QMLKETINEEALND  
ETINNEEALND  
EEAEAEWDRLHFPVAG  
EDRDLHFPVAGPLAP  
LHPVHAGPIARGNMR  
HAGPIARGQREPRG  
IAPGMRPREGSDIA  
QMEEPREGSDIACTS  
PRGSDIACTSLOE  
(60) DIACTTSLQDQJGW

FIGURE 13 contd.

(1) NCGKWKSKRSVYQIPTVRERHRAEPAADCGAVSRDLEKHGATITSSNTAAANNADCWLAQEEREGFPVRPOVPLRPMTYKAADVDSLHFILENGGLEGLYSQKRODILIDLMVHTQGTFDQNYTPRGPGIRYPLTFGMCFKLVPEPEKVEANEGENNSLHPPMSLH  
 (21) VKAADVDSLHFILEKG  
 VDLSHFILEKGLEG  
 HFILEKGLEGKLEG  
 EKCGLEGJLGLIYS  
 KRODILIDLMVHTQG  
 IYSQKRODILIDLMVHTQG  
 LKGJLGLIYSQKRODILID  
 RERHRAEPAADCG  
 RRAEPADCGAVSR  
 PADCGAVSRDLEK  
 GVGAVERDLEKHGAI  
 VSRLDKXHGAISSN  
 (10) LEKHGAIISSENTRAN  
 GAITSSNTAAANNADC  
 AANNADCWLAQEEREG  
 SSNTAANNADCWLAQEER  
 ADCAWLAQEEREG  
 KLEAQEBEBVGPFVR  
 QEEEVGFPRZCQVP  
 EVGFPRZCQVPPLRPM  
 QVPLRPMTYKAADV  
 QVPLRPMTYKAADV  
 (20) RPMTKKAADVDSLH  
 (40) NEGENNSLHPPMSLH

(1) NCGKWKSKRSVYQIPTVRERHRAEPAADCGAVSRDLEKHGATITSSNTAAANNADCWLAQEEREGFPVRPOVPLRPMTYKAADVDSLHFILENGGLEGLYSQKRODILIDLMVHTQGTFDQNYTPRGPGIRYPLTFGMCFKLVPEPEKVEANEGENNSLHPPMSLH  
 (21) VKAADVDSLHFILEKG  
 VDLSHFILEKGLEG  
 HFILEKGLEGKLEG  
 EKCGLEGJLGLIYS  
 KRODILIDLMVHTQG  
 IYSQKRODILIDLMVHTQG  
 LKGJLGLIYSQKRODILID  
 RERHRAEPAADCG  
 RRAEPADCGAVSR  
 PADCGAVSRDLEK  
 GVGAVERDLEKHGAI  
 VSRLDKXHGAISSN  
 (10) LEKHGAIISSENTRAN  
 GAITSSNTAAANNADC  
 AANNADCWLAQEEREG  
 SSNTAANNADCWLAQEER  
 ADCAWLAQEEREG  
 KLEAQEBEBVGPFVR  
 QEEEVGFPRZCQVP  
 EVGFPRZCQVPPLRPM  
 QVPLRPMTYKAADV  
 QVPLRPMTYKAADV  
 (20) RPMTKKAADVDSLH  
 (40) NEGENNSLHPPMSLH

(41) NFGUHPPNSLHGMDDPNEVLLWKFDSRSLAFHIMARELHPEYTKDC  
 (42) NFGUHPPNSLHGMDDPNEVLLWKFDSRSLAFHIMARELHPEYTKDC  
 LPHPSLHGMDDPNEVLLWKFDSRSLAFHIMARELHPEYTKDC  
 SLHGMDDPNEVLLWKFDSRSLAFHIMARELHPEYTKDC  
 MDDPNEVLLWKFDSRSLAFHIMARELHPEYTKDC  
 BREVLVKKEPSRSLAFHIMARELHPEYTKDC  
 LVAKEDSRSLAFHIMARELHPEYTKDC  
 FDSRSLAFHIMARELHPEYTKDC  
 LASHINGARELHPEYTKDC  
 (43) HGRARELHPEYTKDC

FIGURE 14

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FIGURE 15

(41) ETVPVKLKEPDGPKVKQHPLTEEKIKALVIECTEMENKRGKSKIGDENPNPTPVFAIRKKDSTAKWRKLVDPRELINKRTOFWVOLGIPHPAGLKKKSVTVDAYFSVPLDODPRKYTAFTIPISSINNETPQIRYQNVLPQGKGSPAIFOSSMTKILEPPRKQNP  
 VELKPGMIDGPKVKQK  
 FGMDGPKVKQHPLTE  
 GPKVKQHPLTEEKIK  
 RQWELTEEKIKALVAE  
 LTERKIKALVIECTEMEKE  
 KIKALVIECTEMEKE  
 LVEICTEMERKEKIG  
 CTMEEKEGKISKIG  
 (50) EKEGKISKIGPENPY  
 KISKIGPENPTNTPV  
 IGDENPNPTPVFAIK  
 NPYHTPVPAIKKKDS  
 TPVRAIKKDSSTER  
 AIKKDSSTERKLD  
 KDSSTERKLD  
 KDSSTERKLD  
 RELANKLVDPRELINKR  
 LVDPRELINKRTOFW  
 (60). KETODFNEVOLGIPH

(61) DF4WVOLGIPHPAGLK  
 VOLGIPHPAGLK  
 IPHPAGLK  
 AGUKKKSKSVTUV  
 KKSVTUV  
 VTVLDDGDAYPSVPL  
 DVGDAMPSVPLDODPRKY  
 APFSVPLDODPRKY  
 VPLDODPRKYTAFTIPI  
 (70) KDFPRKYTAFTIPISSIN  
 KTYAFTIPISSINNETP  
 FTIPISSINNETP  
 SINKETPGIRYQNVLPQG  
 ETPGIRYQNVLPQG  
 1RYQNVLPQGIRYQNV  
 SINKETPGIRYQNVLPQG  
 YNVLPGNGSPAPIF  
 EOCNKGSAPAFOSSM  
 KGSPAPFOSSMTKIL  
 AFPOSSMTKILEPPR  
 (80) SSMTKILEPPRKQNP

(161) REGEETYTDSCKNSKEGKAGYITDRGKDVKVULEQTNGQAELEAFMLTSGPKANIIVDSQYNGITTCGCPTESESRLVNGQIEEMIKUSSEIYAWTVAHKCIGCIGEIDHLSQGIRYQVIFLEKIEPAQEHDKYHSINVKEVFKFOLPRIVARQIVDTCOKCH  
 (161) ESRLVRQJIBEWIKK  
 VAOIBEMIKSISBY  
 IEEWIKSISBYAVAV  
 IRKSISBYAVAVPAHK  
 EIWWAVAVPAHKCIGG  
 ANTPAHKGIGGNGQEII  
 AHKGIGGNGQEIDHLY  
 ICENQFIDHLSQGI  
 QBDHLSQGIGROVL  
 (190) HLVSQGIGROVLPLEK  
 QGIGROVLPLEKESPA  
 QVLFLEKIEPAQEEH  
 LEKIEPAQEEHDKYH  
 ESPAQEEHDKYHSINV  
 EKHDKYHSINVAKLVP  
 KYHSINVAKLVP  
 KYKELVFKGCLPRIV  
 LVFKELVFKGCLPRIV  
 FGFLPRIVARQIVDTC  
 (200) RIVARQIVDTCOKCH

(170) EPTTNOQAELEAFML  
 NOQAELAEAMLMALTD  
 ELEAFLMALTDGPK  
 PMLALTDGPK  
 LTDGPKANIIVDSQ  
 GEKANIIVDSQYNG  
 NIIVDSQYNGMGIITG  
 DSQYNGMGIITGCEPE  
 YMGIITGCEPESESR  
 ITGCEPESESLVNUO  
 (180) PTESESLVNUOIRE

FIGURE 15 contd

(81) KILEPFRQNDIVYQMDLTVGSDLEIGQHRTKIELQHLLRQFTPDKKHQKBPPTLMCGYBLHBDKWTQPIVLSKOSWYNDIQKLGVGIAWASQIYAGKUKVQLCULRGTKALTEVPLTEAELEAENREILKEPVGUVYDPSKDLIAETQKGQQQ  
 (101) LPEROSWYNDIQKL  
 DSWTNDIQKLUGKL  
 VNDIQKLUGKLWAS  
 QKLUGKLWASQIYVA  
 GKLWASQIYAGKUV  
 WASQIYAGKUVQQLC  
 YAGKUVQQLC  
 IYAGKUVQQLC  
 IYAGKUVQQLC  
 IYAGKUVQQLC  
 (110) LURGCKOLTEVPLT  
 TKAJTSVPLTZEAB  
 PLTEBASLELA  
 EBAELEAENRELLF  
 ELAENTRELLKEPVHO  
 NRELLKEPVHGVYTD  
 LKFVYKGVYDPSKID  
 VHFVYDPSKID  
 VHFVYDPSKID  
 (120) SKDLIAETQKGQQQ

(90) FEELQHLLRQFF  
 ROHLLRQFF  
 LRGFTTPDKKQCKE  
 FTTPDOKKQCKEPPPL  
 DKKQCKEPPPLMAY  
 QKBPFPFLHNGCYBLHP  
 PFLNQYELHPDCKT  
 MCYELHPDCKTQPI  
 LHPDCKTQPIVLP  
 KWTQPIVLPEDSM  
 (100) QPIVLPEDSMNTWD

(121) IARIQKQGQGQTYQIYOBPFKULKTKYARORGANTDVKQLTAVQKATESIVINGKTPKXLPIONETWANWTHQATMIFENRFVNTPLVWLTQPLESKPVAQAEFTYDQAMNRETCKAGYVTDRGRQKVVSLSLTDTNQTELQATHLAVQDSGLSVNTV  
 (141) WQATWIPERFVNTP  
 WIPEBFVNTPLV  
 WEFVNTPPUKWUWQ  
 ATPPLYKLWQLEKE  
 LWKLWQLEKEPVIG  
 HYOLBKBPVICAETP  
 EXSPIVGAASTEVUG  
 IVGAETTYDGAANR  
 ETTYDGAANRETKL  
 TKLGKAGYVTDRGRQ  
 XAGYVTDRGRQKVVSLSLT  
 VTDRGRQKVVSLSLT  
 GRQKVVSLSLT  
 VVSLTTTQKTELQ  
 (150) VDGAANRETKLKAG  
 ANRETKLKAGYVT  
 KIATKATESIVING  
 KIATKATESIVING  
 TPKEKLIPTOKETME  
 ESTVNGKTPKPKLPIQE  
 IWCKTPKPKLPIQE  
 KLIPTOKETME  
 QKETWEAWTIEYWA  
 WEAWTIEYWA  
 (140) WTEWQATWIPERF  
 (160) IHLALQDSGLSVNIV

FIGURE 15 contd

- (161) LDOSGELEVNIYTDQVALGIIQIAQPDKXSESELVSYDIEOLIKKEKVKXLAMYPAHKIGGNEQVDKLVSAGTRKVLFLDCIDKAQEEHEKRYHSNFRAMASDNLKQQLGEAMRQWDCSPGIVTQDCTHLSGCKILIVAVHVAQSGYIEAEVTPAETGQE
- (161) DKAQEEHEKRYHSNFRAMAS  
BENEKTHSNFRAMAS
- GLEVNIVTDQVALGIIQIA  
NIVTDQVALGIIQIA  
DSQVALGIIQIA  
NIVTDQVALGIIQIA  
ALGIIQTDQPSKSE  
IOPQDKSSELVSYQ  
PDKSESELVSYQ  
ESELVSYQIEOLIKK  
VSQIIEOLIKK  
(170) IEQJIKKEKVYLAVV  
IKEKVYLAVVPAHK  
KTYLAVVPAHKIGGG  
AWPAHKIGGNEQV  
AHKIGGNEEQVDLKV  
IGCNEQVDLNSAGI  
EQVDLNSAGIRKVL  
TLNSAGIRKVLFLGS  
AGIRKVLFLGS  
KTYLFLDGDIDKAQBEH  
(180) LEGIDKAQEEHEKRY
- KYHSNFRAMASDFNL  
NIVTDQVALGIIQIA  
MASDFNLNPPEVAKEL  
NPPEVAKELVASC  
PVVAKELVASCDFNL  
KETIVASCDKCOLGE  
ASCDKCOLGEAMHG  
KGZANHGQVDCSPGI  
MEGQVDCSPGIWQD  
VDCSPGIWQDCTH  
PTQDCTHLEGKLIWA  
QIDCTHLEGKLIWA  
THELEGKLIWA  
GCLILVAVHVAQSGYI  
LVAVHVAQSGYIAREV  
HVAVHVAQSGYIAREV  
(190) GYERAEVIPAETGQE
- (201) AEVIPAETQETAYPLKLGKRPVKTITDNGSNFTSTVKAACHWAGIKOEGPYMPQSOFVVESENKELKXIGQVDEHLKTAQOMAVPIHNEKRGEGGYSAGERIVDIAITDQTKELOKQITKIQNSFRTYDSDRDPLNKGPAKLLAKGEGAVWVQDMSDI
- (201) AEVIPAETQETAYP  
PAETQETAYELKL  
QETAYELKLQAGRM  
AYFLQLAGRMVPKT  
LKLAGRMVPKTHTD  
GRFPVKTITDNGSN  
VKZTITDNGSNFTST  
HTDNGSNFTSTTVKA  
GENFTSTTVKA  
(210) TSTTVKA  
VKA  
CRWAGIKOEGFGIPIN  
PMPQSGQVNEVSK  
GNGEPGPINPOSQ  
PMPQSGQVNEVSK  
OSQGVNEVSKELKK  
VWESENKELKKLIGQ  
MNKELKKLIGQVDRDQ  
LKCKLIGQVDRDQAEHL  
(220) ICQVDRDQAEHLTAV
- PAETQETAYPLKLGKRPVKTITDNGSNFTSTVKAACHWAGIKOEGPYMPQSOFVVESENKELKXIGQVDEHLKTAQOMAVPIHNEKRGEGGYSAGERIVDIAITDQTKELOKQITKIQNSFRTYDSDRDPLNKGPAKLLAKGEGAVWVQDMSDI  
(221) ADQAEHLKTAQOMAV  
EHLKTAQOMAVFHN  
TAVQMAVFHNFK  
MAVFHNFKGGGG  
HNFNRKGGGGGGSA  
KRKGGGGGGSGERI  
YSGERIVDIAITDQ  
ERIVDIAITDQTK  
(230) DIATDQTKELOKQ  
TDIQTKELOKRTKI  
TREHQKQTKIONFRVYD  
QKQTKIONFRVYD  
TKIONFRVYDSDRDP  
MFRVYDSDRDPLNKG  
YDSDRDPLNKGPAKLL  
RDPLNKGPAKLLAKG  
WKGPAKLLAKGEGAV  
AKLLWKGEGAVVQD  
(240) WKGEGAVVQDMSDI

FIGURE 15 contd

FIGURE 15 contd

(241) GAVIQQNSDIKVVPRRKAKIIRDYCKQMGDDCVASRQDED  
IQDANSIDIKVYERKA  
SDIKVMPRIKVYERKA  
VVPRRKAKIIRDYCK  
REKAKIIRDYCKQMAC  
IRDYCKQKNAQGDDCV  
YGXQMGDDCVASRQ  
(248) MGDDCVASRQDED

MAGRSQDSDELLKTVRLIKEYLQSNHPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 (1) MAGRSQDSDELLKTVRLIKEYLQSNHPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 SGDSDDELLKTVRLIKEYLQSNHPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 DEELLKTVRLIKEYLQSNHPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 LKTVRLIKEYLQSNHPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 RLIKFLYQSNHPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 FLYQSNHPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 SNRPPSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 PSPECTQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 GTRQARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 (10) ARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 ARRNRMRERQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 WREQRQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 ORQRISIESTYLGRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 RSISEWILSTYLERP  
 RSISEWILSTYLERP  
 EWIISWILSTYLERP  
 EWIISWILSTYLERP  
 GRPAEPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 EPVPLQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 LQLPPLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE  
 (20) PLERLTIDCNECGTSGTQGSPQILVESPAVLESGTKEE

FIGURE 16

(1) MEFYDPRLEPWKHPGSQPKTACTNCYCKKCCFHQCQVCFITKGICISYGRKRRPQDSQTHQVSLSKQFPRGDPTGPKESKKXVIRETEIDPVQ  
DRRLBPRLBPKHFGSQPK  
EPWKBPKHFGSQPKTACT  
HPCGSQPKTACTNCYC  
QPKTACTNCYCKKCC  
ACTNCYCKKCCFHQCQ  
CYCKKCCFHQCQVCFI  
KCCFHQCQVCFITKGL  
KCQVCFITKGICISY  
(10) CFITKGICISYGRKX  
KGICISYGRKRRPQR  
ISYGRKXRRPQRRAP  
RQRERAPQDSQTHQV  
RQKPRQRERAPQDSQ  
DSQTHQVSLSKQPPS  
HOVSLSKQPPASOPRG  
LSKQPPASOPRGDPPTG  
(20) PASOPRDPPTGPKES

(21) PRGDPTGPKESKKX  
PRGPRESKKXVERET  
KESKKXVERETETDJP  
(24) KKVERSTETDPVQ

(21) PRGDPTGPKESKKX  
PRGPRESKKXVERET  
KESKKXVERETETDJP  
(24) KKVERSTETDPVQ

## FIGURE 17

(41) PPLPSVTKLTEDRWNKPEQKTGHRGSHTWNG  
 (42) PPLPSVTKLTEDRWN  
 SVTKLITEDRWNCPQK  
 1TEDRWNCPQKTCGH  
 RWNKPKQKTGHRGSHTWNG  
 PQKTGHRGSHTWNG  
 (43) KEHRESHTWNG

## FIGURE 18

FIGURE 19

(1) MEQAPEDQGQREPMENITLLELKESEAVRHFPRIMHLGLQHQIVETYGDNTAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
PEDIQAPRDQGQREPMENITLLELKESEAVRHFPRIMHLGLQHQIVETYGDNTAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
GPOREPMENITLLELKESEAVRHFPRIMHLGLQHQIVETYGDNTAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
(21) IGTFRQRARGASRS  
(22) QRQRARGASRS

(1) ELLEELKSEAVRHFPP  
ELLKSEAVRHFPRIMHLGLQHQIVETYGDNTAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
EAVRHFPRIMHLGLQHQIVETYGDNTAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
HPRIMHLGLQHQIVETYGDNTAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
(10) IWLHGIGSCHIXETYG  
GIQHQIYETXGDTWA  
HIVETXGDTWA  
TWDGTWAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
TWAGVEAIIIRIQLQLFIFHRIGCQHSRIGITTRQRARGASRS  
VETIRILQDQQLFIFHRIGCQHSRIGITTRQRARGASRS  
IRILQDQQLFIFHRIGCQHSRIGITTRQRARGASRS  
QQLQFIFHRIGCQHSRIGITTRQRARGASRS  
FIHRIGCQHSRIGITTRQRARGASRS  
(10) QHSRIGITTRQRARGASRS

(11) MQSLQILAIVALVVAIIIAIVWSIVFIEYRKILQRKIDRLIDRIRERAEDSGNESECQEEELSALVERGHHAPDWDOL  
QILAIVALVVAIIA  
IVALVVAIIAIVW  
VVAIIAIVWSIVF  
IIAIVWSIVFIEYR  
VWSIVFIEYRKIL  
IIFIEYRKILQRKII  
EYRKILQRKIDRLI  
IIFQERKIDRLIDRIR  
(10) RKIDRLIDRIRTRAS  
RULDRIREPAREDSCN  
RIRERAEDSGNESEC  
RAEDSGNESECQEEELSAL  
SCEQEEELSALVERG  
SECQEEELSALVERG  
QEELSALVERGHHAP  
SALVERGHHAPDWD  
(18) EMGEHAFKWDVDL

FIGURE 20

(1) MSTRPKPORKTKUNTRRPODVKPPCCGQIVCGVYLLPRRGPRALGVATRKTSERSQPRGRQPIKARRPEGRITWAQPGYWPWYGNEGCGWAGMILSBRGSRPSNGETDPRRSRNLTQKVIDLTGPADLNGYIPLVGAPLGAMARL  
 ORKTKKAKTNRKPKTKNTNRR  
 TMRPQDVKFPSGGQIVCG  
 VKEPGCGQIVCGVYLLPR  
 QIVCGVYLLPRCGPRLG  
 LLPRRGPRLGVRATRXTS  
 RLGVRATRXTSERSQPRC  
 RKTSERSQPRGRQPIK  
 QPRGRQPIKARRPEGR  
 (10) PIKARRPEGRITWAQPGY

(11) PEGRITWAQPGYWPWYGN  
 QPGYWPWYGNEGCGWAG  
 LYGECCGAGMILSBRGS  
 GWAQHILSBRGSRPSNG  
 SPRGSRPSNGPDTPRARS  
 SWGPTDPRARSERNLGKV  
 RRSERNLGKVIDTTTCGP  
 GKVIDTLCGFADLMGYI  
 TCGPADLNGYIPLVGAPL  
 (20) MGYIPLVGAPLGAMARL

(21) GAPLGAAARALAHGVRLLEDGVNYATGMLPGCCSPSIFLALLSCLTVASAYQVRNSSGLYHTNDCPNSSIVYEAADAIILHTPCGCVPCREGNASRCIVAVTPPTVATRDCKLPTTQLRHIIDLVGSATLCSALYVGDLGCSV  
 ARALAHGVRLLEDGVNYA  
 VRVLEDGVNKAATGMLPGC  
 VNKATGMLPGCCSFISIPLL  
 LPGCCSFISIPLLMS  
 SPSIFLALLSCLT  
 IFLALLSCLTVASAYQ  
 SCLTVASAYQVRNSSG  
 SAYQVRNSSGLYHTND  
 (30) SSGLYHTNDCPNSSIVY

(31) TNDCPNSSIVYEAADAI  
 SIVYEADAAILHTPCGCV  
 DAIILHTPCGCVPCREGNA  
 GCVPVCYREGNASRCIVAV  
 EGNAASRCHAVAVTPVATR  
 WVAVTPVATRDCKLPT  
 VATRDCKLPTTQLRHIID  
 LPTTQLRHIIDLVGSAT  
 RHIDLVGSATLCSALY  
 (40) GSATLCSALYVGDLGCSV

(41) ALYVGDIQGSVFLVGQLIPTFSPPRHWTQDCNCSTYPCGHITGRHMADKMDMWSPTAALVVAQILRIPOAINDMIACTHMGVLAGIAYFMSWYGMKVALVLLFAGVDAETWITGCSACRTTACUWVLLTGCAGONIQLINTGWHINS  
 CGSVPLVGQLIPTFSPPRH  
 GQLIPTFSPPRHWTQDCN  
 PRHWTQDCNCSTYPCGH  
 QDCNCSTYPCGHITGRHM  
 YPCGHITGRHMADKMDMWSPTAALVVAQILRI  
 HMAHTDMWNSPTAALV  
 MWSPTAALVVAQILRI  
 AALVVAQILRIPOAIND  
 (50) LLRIPOAINDMIACTHMG

(51) IMDMIACTHMGVLAGIAY  
 AHNGVLAGIAYFMSWY  
 GIAYFMSWYGMKVALVLL  
 VENWAKVALVLLFAGVD  
 LVVLLFAGVDAETHWTC  
 AGVDAETHWTCGCSACRT  
 HWTGCSACRTTAGLVGLL  
 GRTTAGLVGLLTGAKQW  
 VELITFGAGONIQLINT  
 (60) ARQNIQLINTGWHINS

(61) INTNGSWKINSTALNCESLMTGHLAGLFLYQKFKNSGCCPERLASCRRLTDEAQCHGPISYANGSGLDRPYCHYPPRCGTIPRKSVCVYPCFTPSPVWVCTTNSCAPTISWANDDUDVWANTTAPPGLNWFGCTWMNSTGFTKVC  
 MCNESLMTGHLAGLFLYQK  
 HINSTALNCESLMTGHL  
 TGWLACLFYQKFKNSGCC  
 FYQKFKNSGCCPERLASC  
 SSGCUPERLASCRRLTDP  
 LASCRRLTDEAQCHGPIS  
 TDFAQGNGPISYANGSGL  
 GPISYANGSGLDERPYCH  
 (70) GSGLDERPYCHYPPRC  
 INTNGSWKINSTALNCESLMTGHLAGLFLYQK  
 MCNESLMTGHLAGLFLYQK  
 HINSTALNCESLMTGHL  
 TGWLACLFYQKFKNSGCC  
 FYQKFKNSGCCPERLASC  
 SSGCUPERLASCRRLTDP  
 LASCRRLTDEAQCHGPIS  
 TDFAQGNGPISYANGSGL  
 GPISYANGSGLDERPYCH  
 (80) GSGLDERPYCHYPPRC

FIGURE 21

(81) MNSIGFTKVGGAPECVIGGYGNTLCLCPTDFRKHEATYSRGSGPHTPRCMVDYFRLWYHPCINTYTFKVRMRYGGVHEUZACMWTGRBODLEDRISESPILLSTQVQLPCTTLPALSTGLIHMNIVDVOXLYG  
 (91) YTFIKVRYMYGGYEVRLS  
 MYUGVHEVHLAACHMYTR  
 HLEAACHTFGRCRDLK  
 GNTLLACPTDCPKHPEA  
 PTDCAPKHPEATYSRGCS  
 HPEATYSRGSGPHTPRCMVTPR  
 RCGSGPHTPRCMVTPY  
 ITPRCMVTPYRMLHYPC  
 DPYRMLHYPCNTYTIP  
 (90) HYECTINYTFKRYMYVG  
 (100) TCIILHQNIVDVOYQYLG

(101) QNIVDVQTLXGVGSIAASWAIKWEVVLFLLLADARVCSCLMQJLISQAEEALBLVILVAAASLAGTHGMSPLVFCPTAHLKGRAVPSAVYAFYGKGPMLLALPORAYALDTEVAASCGVVVLVGLMALTSPYKRTYTSRCMA  
 (111) GLVSEFLVFCFAKYLKGR  
 FFCFAYWLKGRAVPSAVY  
 LKGRAVPSAVYAFYCGTIP  
 GAVYAFYGMPLLLALA  
 GRGPFLLLLALFORAYA  
 LLLFLFORAYALDTEVA  
 RAYALDTEVAASCGVVVL  
 EVAASCGVVVLVGLMALT  
 GVYVGLMALTSPYKRTYTSRCMA  
 (1120) MALTSPYKRTYTSRCMA

(102) QNIVDVQTLXGVGSIAASWAIKWEVVLFLLLADARVC  
 KHEYVVLFLLLADARVC  
 LFLLADARVCSCLMQJL  
 ARVCSCLMQJLISQAEA  
 MELLISQAEEALBLV  
 QAEAMLENLVLMAPSLA  
 NLVLMAPSLAGTAGGNG  
 (110) ASLAGTAGGNGSFLYFFCP

(121) YKRYXISWCMQJLQFLTRVEAQLHVWYPPPLAVGRDAVILMCWVHPTVDEDITCLLIAIFCPLWQSLKVPFVRVQGLRICALARKIACGTYKQWALIJKUGALITGTVYHNLTELDWAHNGCLRDLAVAVEPVVFSRMEKTLI  
 WCMQJLQFLTRVEAQLH  
 YPLTRVEAQLHVWYPPPLA  
 AQLHVWYPPPLAVRCGDA  
 PFLAVRGGRDQVLLMCV  
 GRAYVLLMCVWETLNF  
 LMCVWETLNFEDITLIL  
 TLFEDITLILALFPLN  
 KLLALIFGPMLWQSLI  
 (130) GPMLWQSLKVPYFVR  
 KLLALIFGPMLWQSLI  
 (140) LAVAVEPVFSRMEKTLI

(131) ASLKVUPYKVRGGLR  
 YFVRQGLRICALARKI  
 LLRICALARKIAGGHVQ  
 ARKIAAGHYYQWALIIRLG  
 HYWONAIIRLGALITGTV  
 IKGALITGTVYHNLTPL  
 GTIVVYNHNLTPDRAHNG  
 LTPLDRAHNGCLRDLA  
 ANGLDLA VAEPVFS  
 (150) RGULGCITSLTCRDKQ  
 (151) TTSUTGDRXQVSEVQI  
 DIKQVEGEVQVSEVQI  
 TLTTRGADTAACGDIIN  
 ATTAACGDIINGLAVSAR  
 DIINGLAVSARRGQFIL  
 VSARRGQFILGPADGRW  
 EILGPADGRWKGWALL  
 DGMVSKGRULLAPTAYA  
 WULLAPITAYAQQTGCLL  
 TAYAQQTGCLLACGICLTSI  
 (152) RGMVSKGRULLAPTAYA  
 (153) TCTNGVCMVYHGAGTRT  
 WTVYHGAGTRTIAASPCKP  
 GTRTIAASPCKPVIQMTX  
 PKGPVICKPDTWVDDQDLV3  
 (154) MPTINVDDQDLVWVAPQGS

FIGURE 21 contd

FIGURE 21 contd

FIGURE 2.1 contd

(321) LSAPSLKATCTPANDSPDABELJEBANLWQEMGNIYRVESENKVWILDSFDPLVAEEDEREVSVPAEILRKSRPARALPWARDYNPLVETKKPDYEPVVHGCPLPPRSPPVPPPRKRTVVLTESTISPLAELATKSFGSSS

(331) RKSRRPARALPWARDYNPLVET  
ARCTANHDSPDAAELJBN  
DSPASLIBANLWQEM  
IEANLWQEMGNIYR  
IYRVESENKVWILDSFDP  
NKVWILDSFDPLVNEDE  
SFDELVAREDEREVSYPA  
EEDEREVSYPAEILRKSR  
(330) SYPABILRKSRPARALP

(341) ELATKSFGSSSTISGLTNDNTTSSEPSGCPPDSEUVEYSMPPLEGEPCGDPUISGSKREGDSTVSSGAUTEDWCCSMSVWTGALUTPCRAEIQKLPIMALNSLLRHNLVYTTSRACQR  
GSSSTSGTGDNNTTSSE  
ITGDNTTTSSEPSGCP  
TSSEPARSGCPPDSCWES  
SGCPPDSDVSYESK  
DVESYSSRPPLEGEPGCP  
NPPLEGEPGDDLSGSK  
PGDDLSGSKSTVSGA  
(350) DGSKSTVSGACDTD

(351) TUSSGACDTDWIC  
SSGACDTDVCCSMS  
DTEDWCCSMSXSH  
DVCCSMSXSHTGAL  
CSMSISHTGALVTP  
SISWTGALVTPCAEEQK  
LVTPCAGEEQKUDINTL  
EEQKLFINALNSLURH  
NALNSLURHNLVYTT  
(360) LMRHNLVYTTSRACQR

(361) YSTTSRSACQGQRKVTFDRQYLDKXQDVKVAKASERKVNLLSVBACSLTPHSASKPKGYGRKDVRCHARKAVAHINSYKDLLEDSTPDTTIMAKNEWFCVQPEKGORKPARLYFPDLGVRYCEKRALYDVSKLPLAVMG  
ACQRQKRVTFDRQYLD  
YTFDRQYLDKHYQYLUK  
YLDKHYQYLUKEVKAAS  
PAASKVANLVEBACS  
ANLVEVERACSLTPPHSA  
PHSAKSKFSGAKDVRCH  
FEGAKDVRCHARKAVAH  
(370) FEGAKDVRCHARKAVAH

(381) YVSKLPLAVWSSYGFDSYGPORVEETYQAWKSKTPTGFSYDTCRDESTVTSDIRTEAIYQCDLDPQARYAISLTERIYVGGPFTNSRGNCYRASGULTSCENTLTYIKARAACRAAGLQDCTMLVCGDDLWVCESSAG  
AVNGSSYGPORVE  
GPOYSPGPORVEFVQAWK  
QREFEVYQAWKSKTPTG  
QAWKSKTPTGFSYDTC  
TMQFSYDTCRCPDSTVTS  
DTRCPDSTVTSDIRTE  
TVTKSDRTEAIYQCD  
RTBEAIYQCDLDPQARY  
(390) QCQCDLDPQARYAISL

(391) QARYAISLTERIYVGGP  
ELTERIYVGGPFTNSRCE  
VGGPFTNSRGENGCYRASGUL  
YRERCRASGVLTSCENTL  
GNTLTCYTKARAACRAAG  
IKARAACRAAGLQDCTML  
RAGLQDCTMLVCGDDLW  
(400) CTMUVCDLWVCESSAG

FIGURE 21 contd

(401) DDLVVICESAGQEDAASSLRAFTEAATRYSAPPGDPQQPEYDLELITSCSSNVSVANDGAGKRVYTILTROPTPLARAAMETARHTPVNSTLGNITIMFAPTLYARMILANTHFFSVLIAARDQLEQALNICHYGCACYSIEPLDUPP  
 (411) PTPLARAAMETARHTPV  
 AAKEТАРHTPVNSHЛГНТ  
 ET PVNSHЛГНТ IMFAPTЛ  
 LGNIMFAPTЛWARMILM  
 APTLWARMILMTHFFSVL  
 FSVLIMFAPTЛWARMILM  
 MILMTHFFSVLIAARDQLE  
 DQEQLANCIЕYGCACYSI  
 НСЕИYGCACYSIEPLD  
 (420) YGCACYSIEPLDUPP

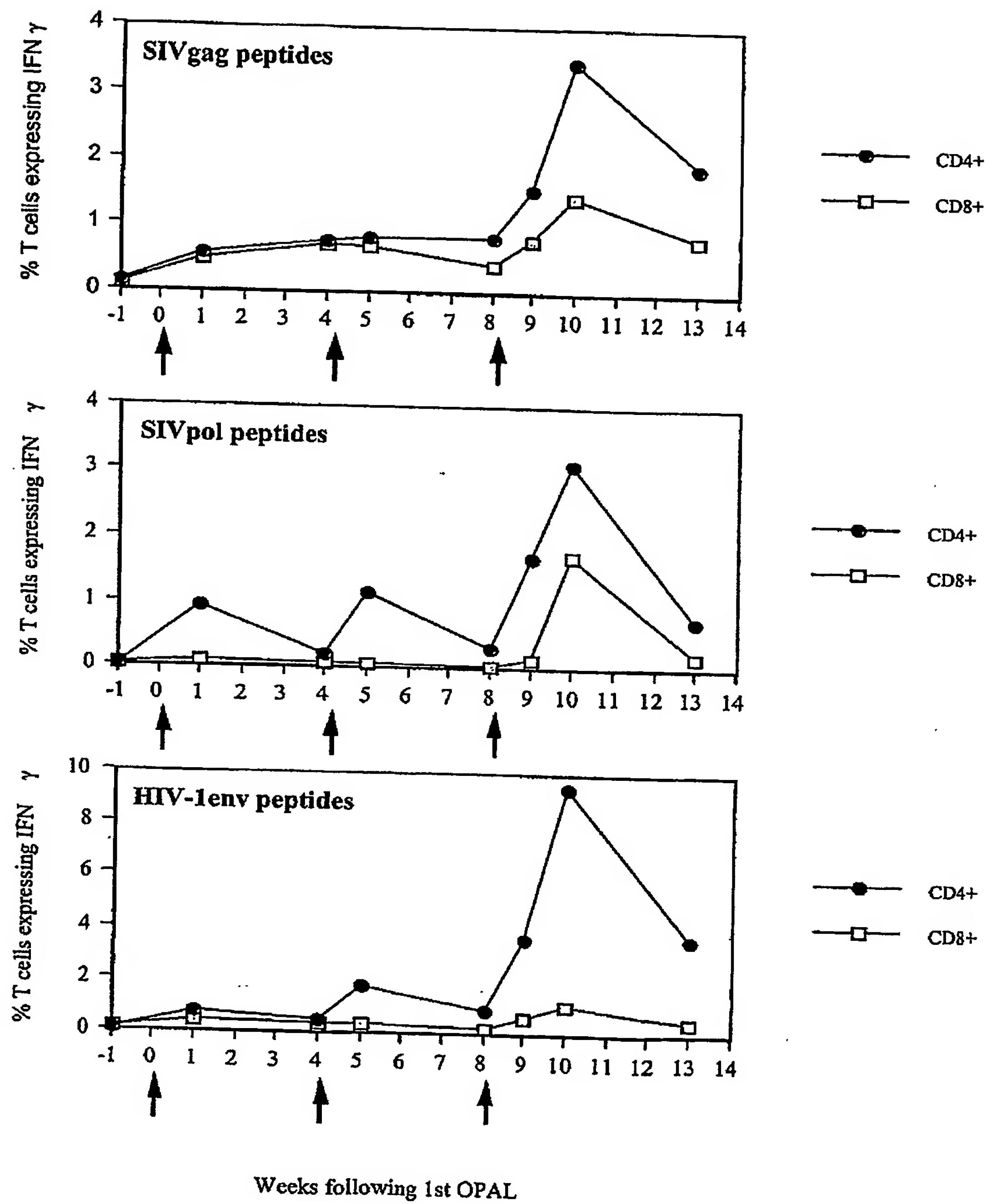
(421) CYSIEPLDUPPIIQRЛХОЛСАФSLHSYSPEBINRVAAACLRLKGPPPLRANTHРАРСVRAPELLRGGRAATCGKYLENMAУTKLTKLTP  
 (431) CGKYLENMAУTKLTKLTP  
 KAVTЛKLTKLTPMAAGRL  
 KLTPIAAAGRДLSSGFT  
 AGRLDLSGFTAGYSGGD  
 GIFTAGYSGGDIYHSYSH  
 SGCDIYHSYSHARPERW  
 SVSHARPERWFCCLLMLA  
 RWFWFCCLLMLAAGVG  
 FCLLMLAAGVGIXL  
 (440) MIAAGVGIVLIPN

(401) DDLVVICESAGQEDAASSLRAFTEAATRYSAPPGDPQQPEYDLELITSCSSNVSVANDGAGKRVYTILTROPTPLARAAMETARHTPVNSTLGNITIMFAPTLYARMILANTHFFSVLIAARDQLEQALNICHYGCACYSIEPLDUPP  
 (411) PTPLARAAMETARHTPV  
 AAKEТАРHTPVNSHЛГНТ  
 ET PVNSHЛГНТ IMFAPTЛ  
 LGNIMFAPTЛWARMILM  
 APTLWARMILMTHFFSVL  
 FSVLIMFAPTЛWARMILM  
 MILMTHFFSVLIAARDQLE  
 DQEQLANCIЕYGCACYSI  
 НСЕИYGCACYSIEPLD  
 (420) YGCACYSIEPLDUPP

(421) CYSIEPLDUPPIIQRЛХОЛСАФSLHSYSPEBINRVAAACLRLKGPPPLRANTHРАРСVRAPELLRGGRAATCGKYLENMAУTKLTKLTP  
 (431) CGKYLENMAУTKLTKLTP  
 KAVTЛKLTKLTPMAAGRL  
 KLTPIAAAGRДLSSGFT  
 AGRLDLSGFTAGYSGGD  
 GIFTAGYSGGDIYHSYSH  
 SGCDIYHSYSHARPERW  
 SVSHARPERWFCCLLMLA  
 RWFWFCCLLMLAAGVG  
 FCLLMLAAGVGIXL  
 (440) MIAAGVGIVLIPN

FIGURE 21 contd

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Weeks following 1st OPAL

FIGURE 22

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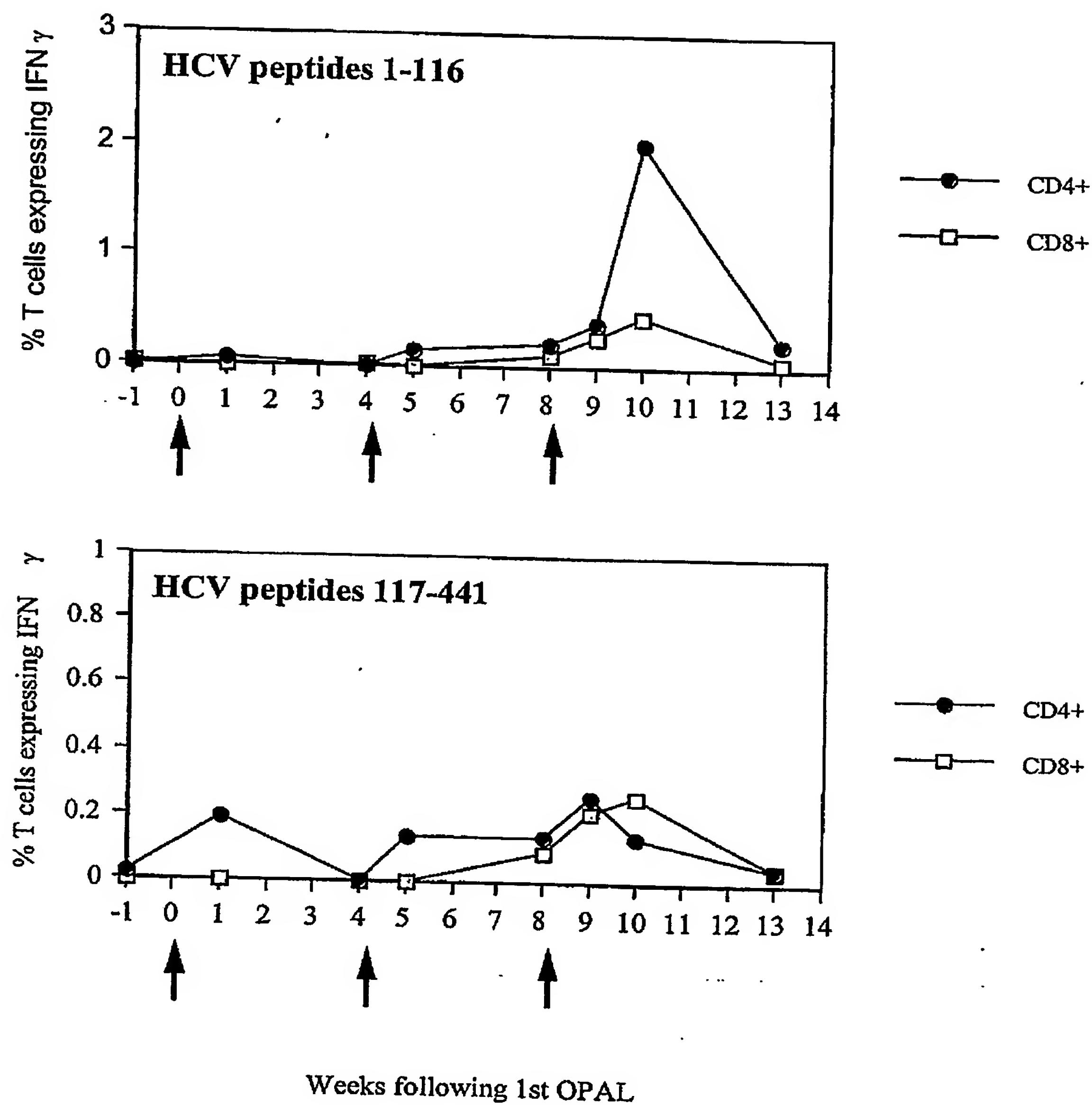


FIGURE 23

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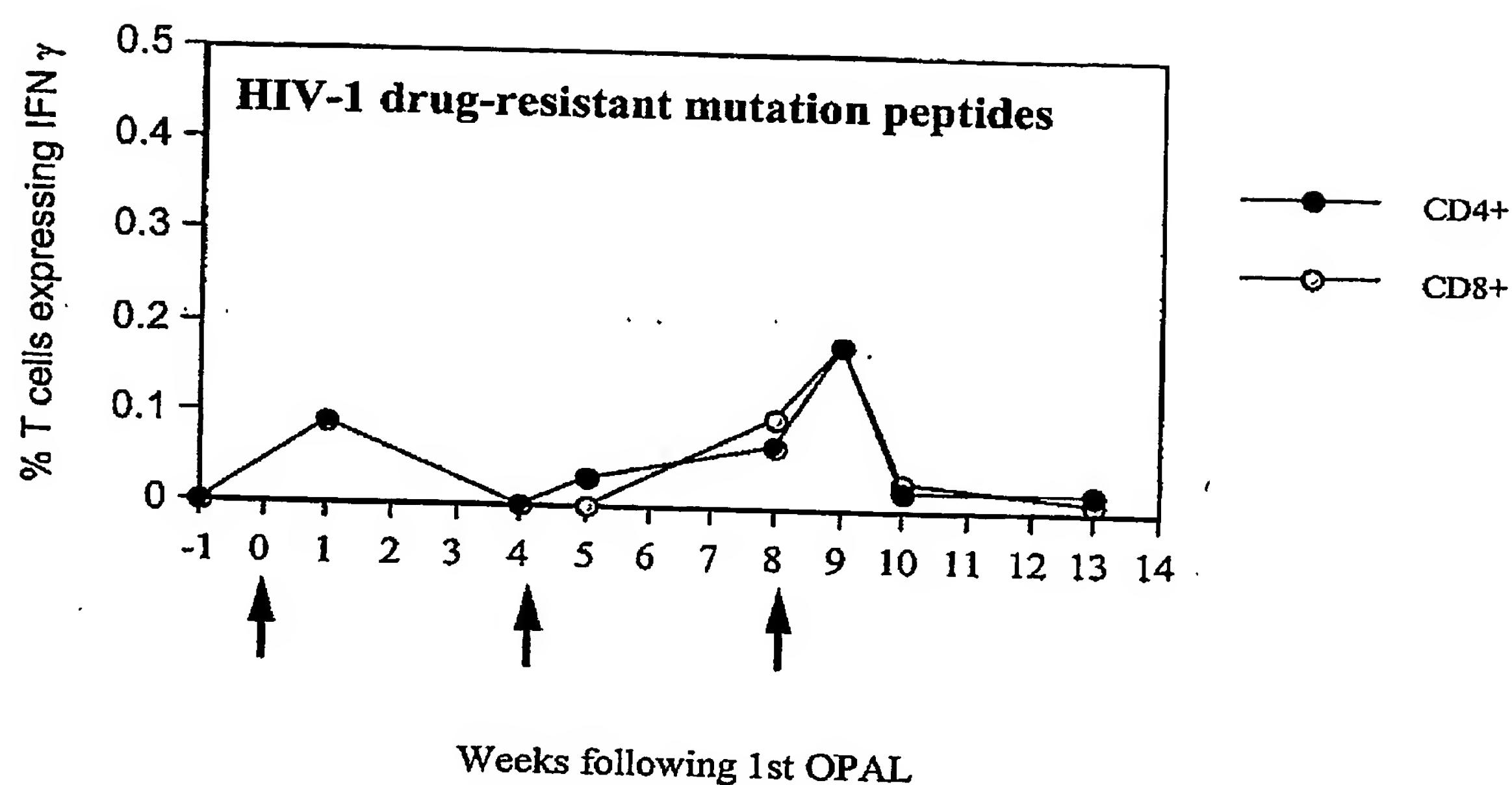


FIGURE 24

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## RT (reverse transcriptase) enzyme of HIV-1

1 -----KVVKQWPLTEEKI KALVEICTEMEKEGKISKI 50  
51 GPENPYNTPVFAIKKKDSTKWRKLVDRELNKRTQDFWEVQLGIPHPAGL 100  
101 KKKKSVTLDVGDAYFSVPLDKDFRKYTAFTIPSINNETPGIRYQYNVLP 150  
151 QGWKGSPAIFQSSMTKILEPFRKQNPDIVIYQYMDDLYVGSDLEIGQHRT 200  
201 KIEELRQHLLRWGFTTPDKKHQKEPPFLWMGYEL 234

### 17mer peptide      Known HIV-1 drug resistance site

ALVEICTELEKEGKISK	M41L
EICTEMEKGKISKIGP	E44D
NTPVFAIKRKDSTKWRK	K65R
PVFAIKKKNSTKWRKLV	D67N
FAIKKKDSDKWRKLVDF	T69D
AIKKKDSTRWRKLVDFR	K70R
KDSTKWRKVVFRELNK	L74V
DSTKWRKLTDRELNR	V75T
VQLGI PHPGGLKKKSV	A98G
PHPAGLKKNKSNTVLDV	K103N
DVGDAYFSIPLDKDFRK	V118I
RYQYNVLPMSGWKGSPA	Q151M
KQNPDIVICQYMDLYV	Y181C
PDIVIYQYVDDLYVGSD	M184V
PDIVIYQYIDDLVVGSD	M184I
IYQYMDLLVGSDLEIG	Y188L
QYMDLYVASDLEIGQH	G190A
IEELRQHLLRWGFTTPD	L210W (also contains T215F as L210W follows 215 mutation)
QHLLRWGFTTPDKKHQK	T215F
QHLLRWGFTTPDKKHQK	T215Y
RWGFTTPDQKHQKEPPF	K219Q

## Protease enzyme of HIV-1

1 PQITLWQRPLVTIKIGGQLKEALLDTGADDTVLEEMNLPGRWPKMIGGI 50  
51 GGFPIKVRQYDQILIEICGHKAIGTVLVGPTPVNIIGRNLLTQIGCTLNF 99

### 17mer peptide      Known HIV-1 drug resistance site

QITLWQRPIVTIKIGGQ	L10I
TIKIGGQLREALLDTG	K20R
ALLDTGADNTVLEEMNL	D30N
LPGRWPKIIGGIGGFI	M46I
GRWPKPMIVGIGGFIKV	G48V
WKPKMIGGVGGFIKVRQ	I50V
KMIGGIGGLIKVRQYDQ	F53L
MIGGIGGFVKVRQYDQI	I54V
KVRQYDQIPIEICGHKA	L63P
TVLVGPTPANIIGRNLL	V82A
TVLVGPTPTNIIGRNLL	V82T
LVGPTPVNVIGRNLLTQ	I84V
VNIIGRNLMQTQIGCTLN	L90M

# FIGURE 25